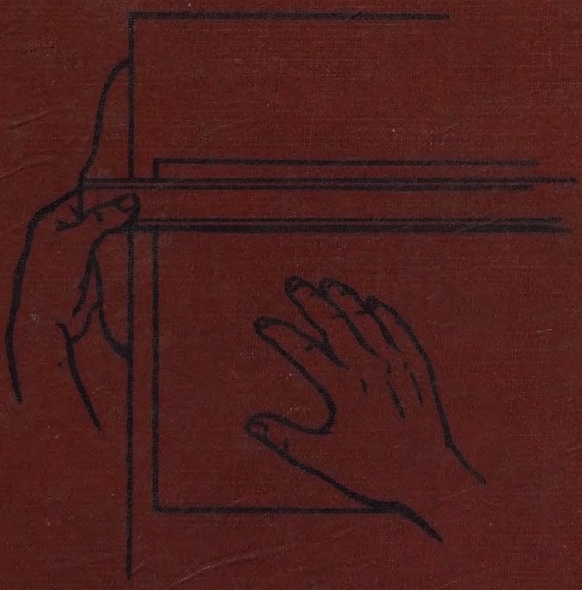
MECHANICAL DRAWING



FRENCH AND SVENSEN

MECHANICAL DRAWING

MECHANICAL DRAWING

A Text with Problem Layouts

BY

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FOURTH EDITION
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PREFACE TO THE FOURTH EDITION

Each revision of this book has been designed to reflect the desires and ideals of the secondary school teachers of mechanical drawing and to keep abreast of the progressively higher standards which they demand. The present edition continues this policy.

The number of chapters has been increased from thirteen to nineteen. The entire text has been rewritten and clarified; most of the illustrations have been redrawn or improved and a large number of new illustrations has been added; and an entirely new chapter on Architectural Drafting replaces the previous one. There are a number of new chapters including Sketching, Structural Drafting, and Map Drafting.

Changes have been made to conform with the "Standards for Drawings and Drafting Room Practice" as adopted by the American Standards Association. One of the major changes is the increase in the size of the drawing sheets which are now American Standard ($11'' \times 17''$). Other changes have been made throughout the book to bring it into agreement with the various American Standards adopted since the last revision.

As in the past, the authors are indebted to their friends, the teachers of mechanical drawing, who, by their personal interest and valuable suggestions, have made it possible to provide a teaching medium adapted to their requirements.

T. E. F.
C. L. S.

PREFACE TO THE FIRST EDITION

Industrial educators are generally agreed that a textbook is necessary for the most successful teaching of mechanical drawing. However, several important considerations are involved in the selection of a suitable text. It "should be more than a collection of problems. It should present the subject in a clear, orderly and logical arrangement of the divisions, explaining *why* each rule or custom is made, and illustrating with examples representing good modern practice."

A survey of mechanical drawing in high schools* recently made by the authors showed that "a system of standardization appears to be needed to give the subject the standing to which it is entitled as a cultural subject as well as a practical one, a real language to be studied and taught in the same way as any other language."

The purpose of this book is to present mechanical drawing as a definite educational subject with the following objectives:

To develop the power of visualization;

To strengthen the constructive imagination;

To train in exactness of thought;

To teach how to read and write the language of the industries;

To give modern commercial practice in making working drawings.

The standardizing of mechanical drawing by the logical arrangement of its subject matter into grand divisions will, it is believed, make both teaching and learning easier.

The first seven chapters comprise a complete textbook which may be used with any problems. The paragraphs are numbered for easy reference. The eighth chapter is a complete problem book, in which the number of problems in each division is such that a selection may be made for students of varying ability, and that a variation from year to year may be had. The problems have references to articles in the text, and the order may be varied to suit the particular needs of a school. Definite specifications and layouts are given for most of the problems, thus making it possible for the instructor to use his time efficiently in

*Bulletin issued by Department of Public Instruction, State of Ohio.

teaching rather than in the drudgery of detail, while the time ordinarily wasted by the pupil in getting started can be used in actual drawing.

More than enough is included for two years' work in the average high school. The authors will at any time be pleased to advise in the selection of problems or arrangement of courses.

T. E. F.
C. L. S.

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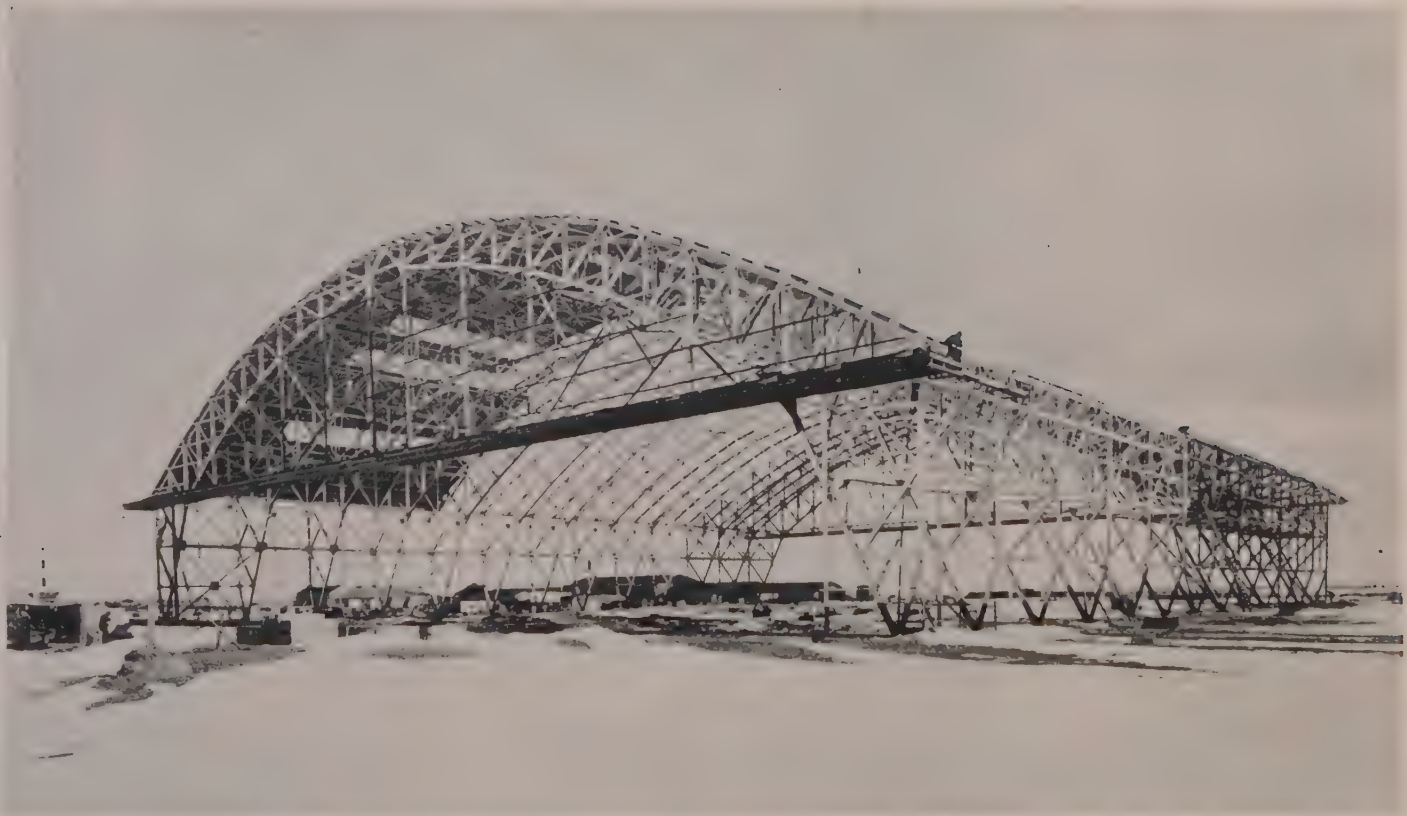


FIG. 1.—A photograph of the steel framework of Hanger No. 1, Lowry Field, Colo., designed and erected by the Construction Division, Office of Quartermaster General, War Department, U. S. A.

MECHANICAL DRAWING

CHAPTER I

THE LANGUAGE OF DRAWING

1. Language is defined as the expression of thought. Every educated person wishes to be able to express himself readily and easily, to convey his thoughts so accurately that they cannot be misunderstood, and to be able to understand the exact meaning expressed by another person. For this reason we make an extended study of English, until we know its grammar and idioms and style. We read literature and practice composition in order to become thoroughly familiar with the language.

2. But if we attempt to describe in words the appearance and details of a machine or bridge or building, we find it not only difficult but in most cases impossible. Here we must use another language, the universal graphic language of drawing. Thus when words fail to give a complete or accurate description, we find books, magazines and newspapers using pictures, diagrams and drawings of various kinds. The use of photographs is the commonest and most familiar form of illustration (Fig. 1). To show a structure pictorially, as it actually appears to the eye, or as it will appear when built, perspective drawing is often used (Fig. 2).

A written description of a new piece of furniture would have to be very long to tell *all* about it and even then might be misunderstood. A picture of it would serve the purpose much better, but the picture would not show the exact method of construction. It would give only the external appearance without telling what was inside. It would be impossible to construct a locomotive or an airplane from either a word description or a picture.

3. Fortunately another form of description has been developed by which the exact shape of every detail of any structure may be defined accurately and quickly. This method consists of the making of a series of views arranged according to a definite system, with figures added to tell the sizes. This is known as "mechani-

cal drawing," and it forms so important a part of all industrial and mechanical work that it is called the "language of industry."

The language of drawing has its own orthography and grammar and style, its own idioms and abbreviations, and its study not only gives one the ability to express thoughts hitherto impossible but develops the constructive imagination and the habit of exact thinking.

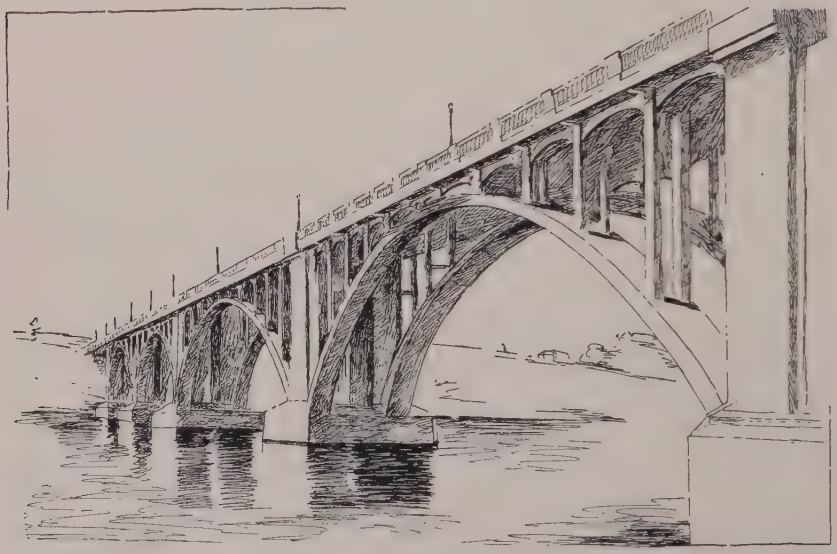


FIG. 2.—A perspective drawing.

4. Learning drawing then is much more than simply learning how to draw. It is learning to read and write a new language, just as real a language as English or French. Its mastery requires study and practice, with close attention to details, but its importance to anyone who expects to go into any branch of technical designing or manufacturing or building justifies all the time spent in studying it.

CHAPTER II

LEARNING TO DRAW

5. Engineering work of all kinds starts in the drafting room (Fig. 3) where the designs are worked out and the necessary drawings are made and checked. The previous chapter explained the necessity for drawing in all industrial work and that it was really a new language. Sometimes drawings are made freehand, but for accurate work it is necessary to use instruments. In learning to read and write in this language we must first learn what tools and instruments to use, and how to use them accurately, skillfully and quickly.

FIG. 3.—A drafting room. (*Monarch Machine Tool Company, Sidney, Ohio.*)

6. Attaching the Paper.—Mechanical drawings are usually made on fairly heavy unruled paper, either cream color or white, which is held in place on a soft pine drawing board by thumb tacks. The drawing board must have its left-hand or working edge straight. Many drafting rooms now use tracing paper or pencil cloth upon which drawings are made directly in pencil and blue printed.

In fastening the paper, place it on the drawing board with the left edge an inch or so from the left edge of the board, place

the T-square in the position of Fig. 4 and "true up" the paper with the T-square blade. Holding the paper in position, move the T-square down, as in Fig. 5, and put a thumb tack through each of the corners, pushing them in until the heads clamp the paper. For sheets of firm drawing paper not larger than $12'' \times 18''$ (to trim to American Standard size $11'' \times 17''$), the two lower tacks may be omitted.

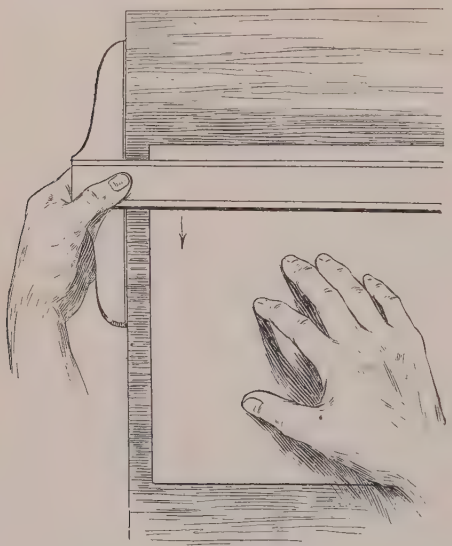


Fig. 4.—Adjusting the paper.

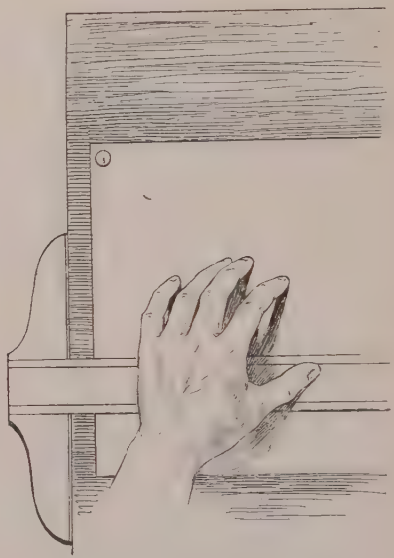


Fig. 5.—Fastening the paper.

7. Sharpening the Pencil.—A draftsman generally uses a hard pencil with a long sharp point so that his work may be very accurate. Drawing pencils are graded by letters from 6B (very soft and black), 5B, 4B, 3B, 2B, B, HB, F, H, 2H, 3H, 4H, 5H, 6H, 7H, 8H, 9H (extremely hard). 4H and 6H are the usual grades of hard pencils used for drawing lines, while F, H and 2H are used for sketching and lettering. The ordinary No. 2 writing pencil is about the same grade as HB or F. Pencil tracings for blue printing are generally made with the F and H pencils.

Sharpen the pencil by cutting away the wood at a long slope, as shown in Fig. 6 at *A*, being careful not to cut the lead, but exposing it about a quarter of an inch. Then shape the lead to a long conical point, as at *B* and *C*, rubbing it back and fourth on a sandpaper pad or fine file, rotating it slowly in the fingers.

Some draftsmen prefer a flat or chisel point, as at *D*, especially for drawings with a large number of long straight lines. Have

this sharpener at hand and keep the lead sharp by frequent rubbing.

Never sharpen a pencil over the drawing board.

Pencil lines must be fine, light, clear lines. Get the habit of rotating the pencil so as to keep a sharp cone on the point.

The foundation of mechanical drawing is the line, so a set of the different kinds of lines used is called the "alphabet of lines." These are explained in Art. 77 on page 67, which gives the line symbols adopted by the American Standards Association.

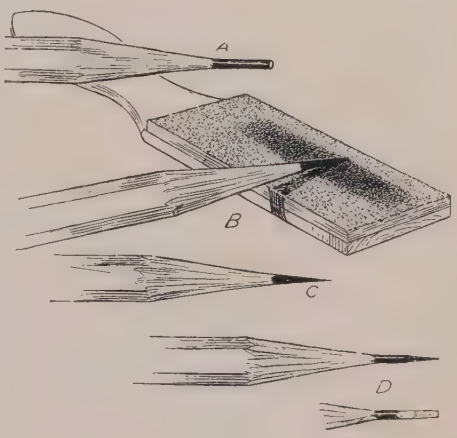


FIG. 6.—Sharpening the pencil.

8. Ruling Lines.—All the lines in a mechanical drawing are made with the aid of some instrument as a guide for the pencil or pen. Horizontal lines are always drawn with the upper edge of the T-square blade as a guide. Hold the head of the T-square against the left-hand edge of the board with the left hand,[1] and always move the pencil from left to right (Fig. 7).

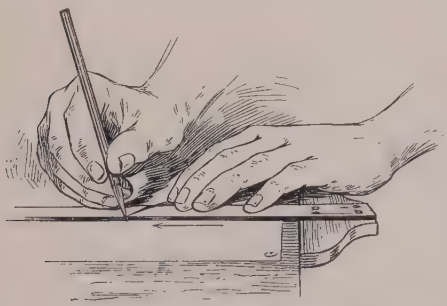


FIG. 7.—Drawing a horizontal line.

The pencil should be held about an inch from the point and inclined slightly in the direction in which the line is being drawn. A plane through the pencil and the line being drawn should make right angles with the paper. This will keep the point of the lead away from the corner formed by the guiding edge of the T-square blade. A little practice may be necessary in order to keep the line parallel to the guiding edge.

Vertical lines are drawn using a triangle held against the T-square. Always have the vertical edge of the triangle toward the left and draw upward from the bottom toward the top (Fig. 8).

[1] Left-handed persons reverse this rule, using the T-square on the right edge.

The 45° triangle has two angles of 45° and one of 90°. The 30°–60° triangle has angles of 30°, 60° and 90° (Fig. 9).

Inclined lines at 45° are drawn with the 45° triangle held against the T-square (Fig. 9). Inclined lines at 30° and 60° are

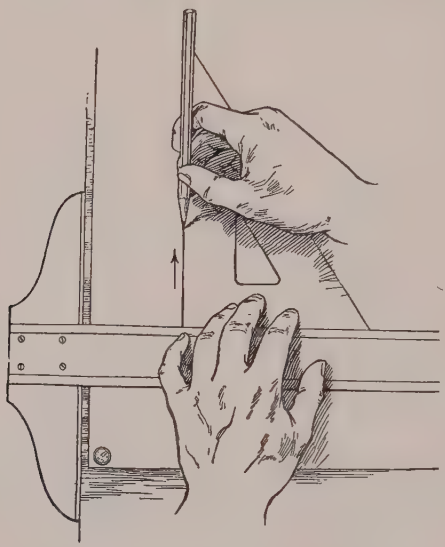


FIG. 8.—Drawing a vertical line.

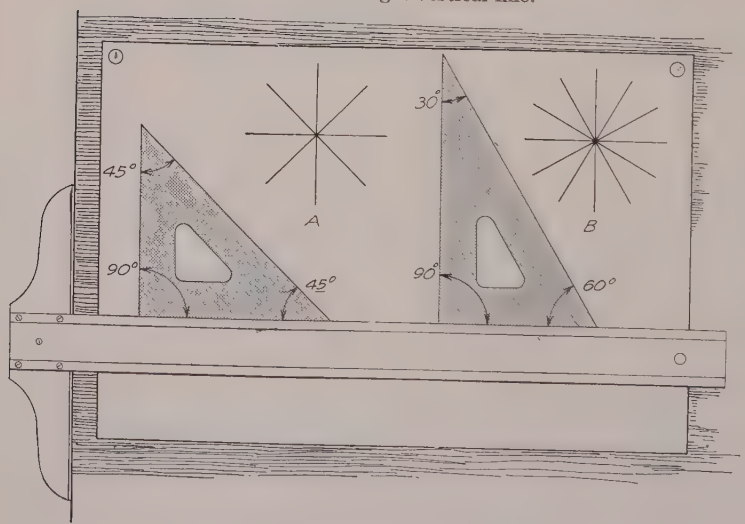


FIG. 9.—The 45° and 30°—60° triangles.

drawn with the 30°–60° triangle held against the T-square (Fig. 9). Lines at other angles varying by 15° may be drawn by using the two triangles in combination with the T-square. The methods of obtaining the different angles are shown in Fig. 10.

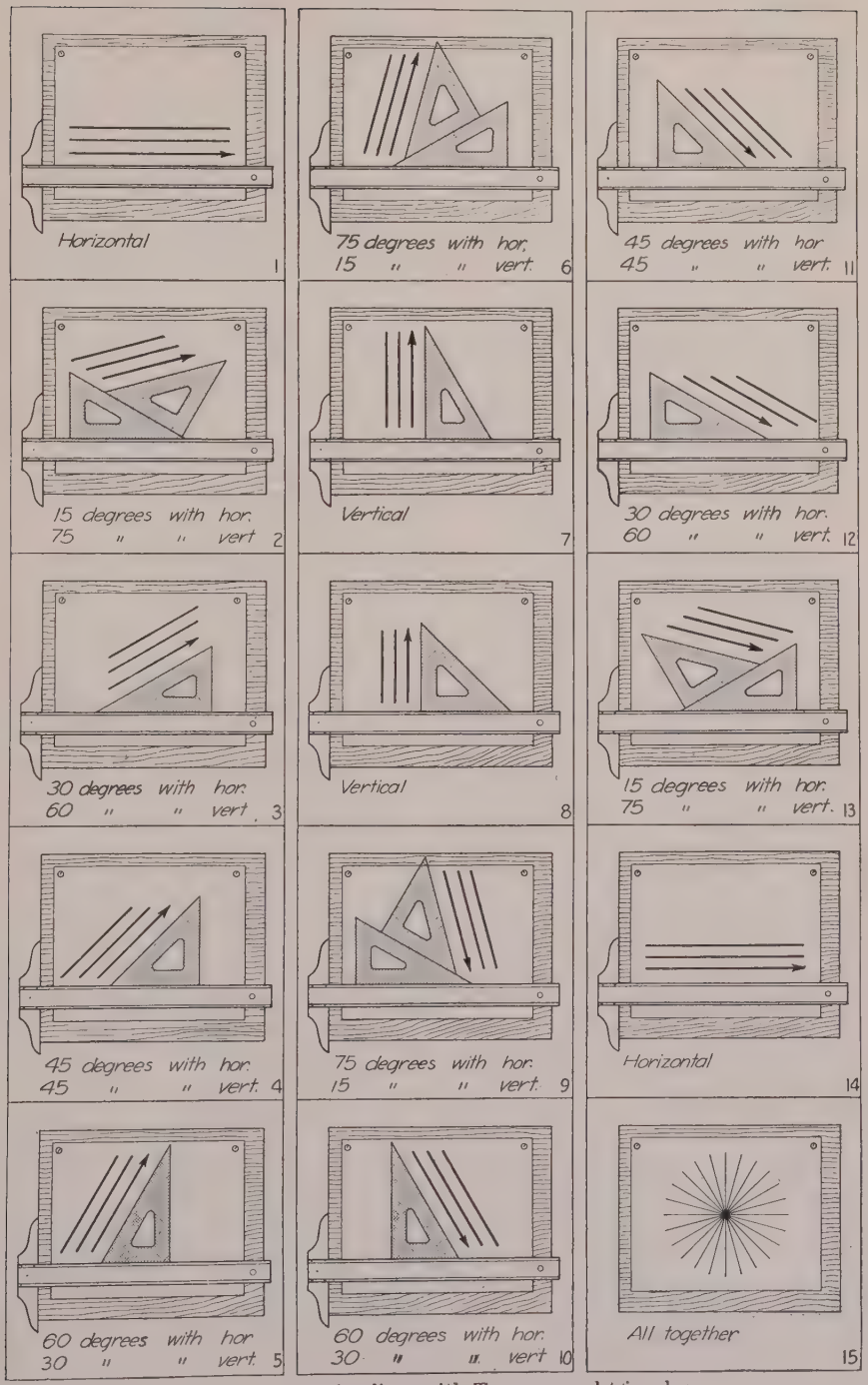


FIG. 10.—Drawing lines with T-square and triangles.

9. Parallel lines—other than horizontal—are drawn by using a triangle in combination with a T-square (or other triangle), as shown in the "movie" of Fig. 11. To draw a line parallel to

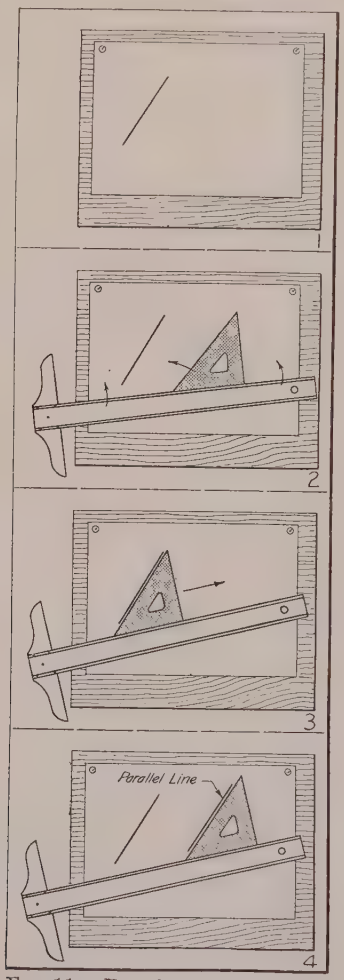


Fig. 11.—Drawing a parallel line.

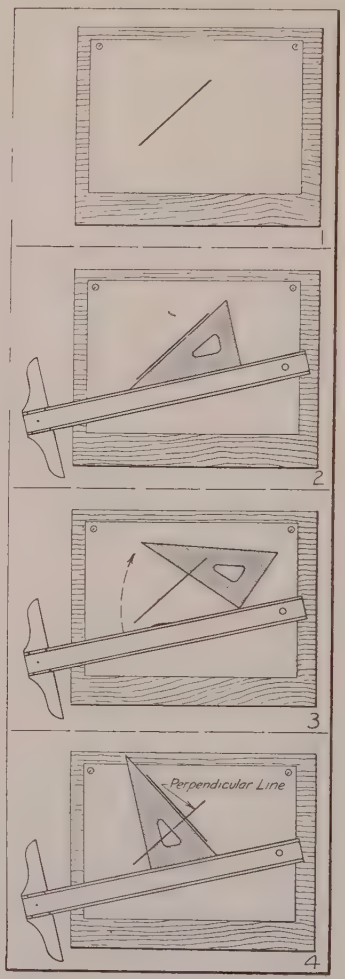


Fig. 12.—Drawing a perpendicular line.

the given line (1), place a triangle against the T-square (2), and move them together until the hypotenuse of the triangle matches the line (3). Hold the T-square firmly, and slide the triangle in the direction of the arrow until the desired position of the parallel line is reached (4).

10. Lines perpendicular to each other may be drawn by using a triangle in combination with the T-square (or other triangle) as

shown in the "movie" of Fig. 12. To draw a line perpendicular to a given line (1), place a triangle against the T-square and move them together until the hypotenuse of the triangle touches the line, as at (2). Turn the triangle about its right-angled corner as indicated at (3), until it is in the position shown at (4) when the perpendicular line can be drawn on the hypotenuse of the triangle.

11. Drawing Arcs.—Drawings are made up of straight lines and curved lines. Most of the curved lines are circles or parts of

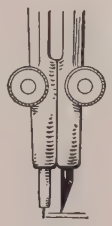


FIG. 13.

circles (arcs). Circles larger than one and one-half or two inches in diameter are drawn with the large compasses. Sharpen the lead as shown in Fig. 13, then adjust the shouldered end of the needle point until it is a very little longer than the pencil point, as indicated in full size in the illustration. The compasses are manipulated entirely with the right hand (see Fig. 14). They are opened by pinching between thumb and second finger (1) and set to the proper radius by placing the needle point at the center and adjusting the pencil leg with the first and second fingers (2). When the radius is set, raise the fingers to the handle (3) and revolve the compasses by twirling the handle between the thumb and finger. Start the arc near the lower side and revolve clockwise (4), inclining the compasses slightly in the direction of the line. Do not force the needle point way into the paper or bore a hole at the center.

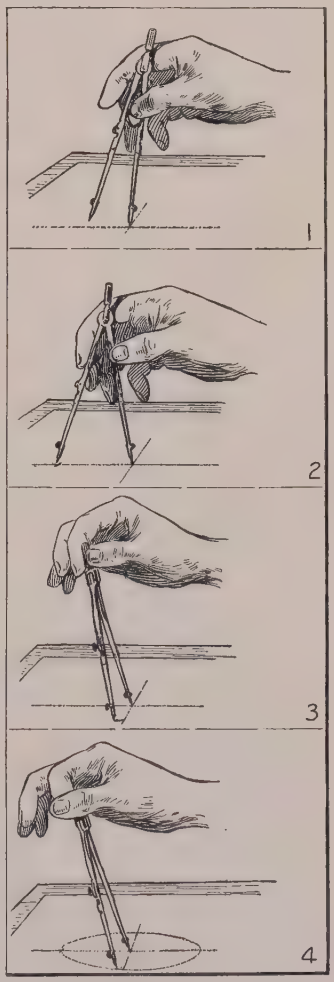


FIG. 14.—Using the compasses.

Small circles and arcs are drawn with the bow pencil, as shown in Fig. 15. In changing side-screw instruments from a small to a large radius, hold the legs together with one hand and spin the nut with the other, in order to save wear on the threads, as shown at (1), Fig. 15. It is also necessary to release the instrument carefully to prevent striking the nut and stripping the threads. Always be sure to relieve the springs of all bow instruments when putting them away.

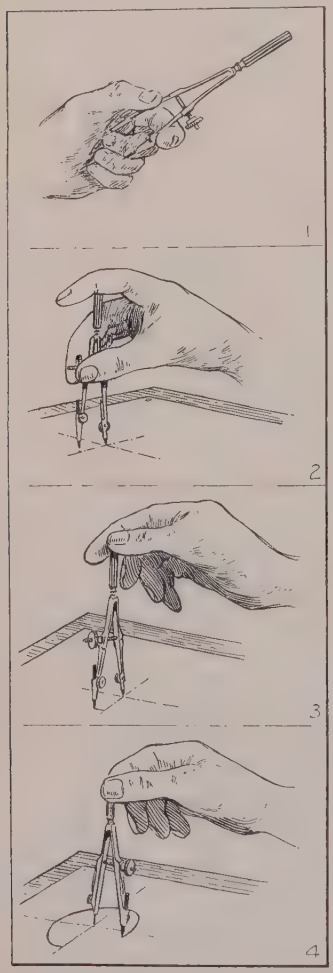


Fig. 15.—Using the bow pencil.

To draw a circle with the bow pencil, adjust the lead and needle point as described for the compasses, Fig. 13, and set the radius as shown at (2) in Fig. 15. Press the needle point into the paper just enough to keep it from slipping. Start the circle on the lower part of the vertical center line (3) and revolve clockwise as indicated at (4).

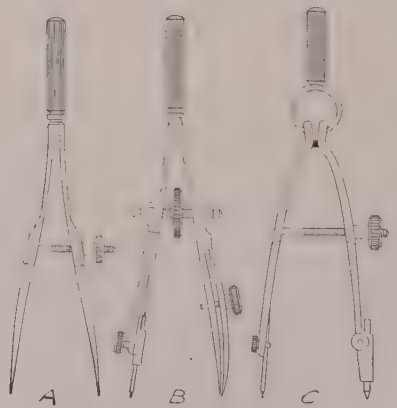


Fig. 16.—Bow instruments.

A set of bow instruments is shown in Fig. 16 and consists of the bow spacers *A*, bow pen *B* and bow pencil *C*. Any one of them may be any one of the three patterns shown, side screw *A*, center screw *B* or ring bow *C*. For a set, all three instruments would, of course, be of the same pattern. The choice of pattern is a matter of personal preference. Some draftsmen consider the center-screw pattern to be more quickly operated and to hold the radius more securely than the other patterns.

12. Curves which are not circle arcs are drawn with the "irregular" or "French" curve. These come in a number of different forms and sizes. The curve is fitted by trial against a part of the line to be drawn, then shifted to match the next portion and so on (Fig. 17). Do not try to go too far with one setting or position of the curve. In general, each new position should fit at least three points on the part of the line just drawn. It is also necessary to notice whether the radius of the curve is increasing or decreasing and to place the curve accordingly.

13. Measuring.—All measurements of lengths or distances on a drawing are made with the *scale*. Scales are made with different divisions for different purposes. For machine, structural and architectural drawing, the mechanical engineers' (or architects') scale of proportional feet and inches is used. For school purposes the triangular scale (Fig. 18) is much used although the flat shapes are preferred by many draftsmen. The symbol ′ is generally used for feet and ″ for inches. Thus three feet four and one-half inches is written 3′-4½″. When all the dimensions are in inches, it is usual practice to omit the symbol.

When the object is not too large for the paper, it is drawn in its full size, using the scale of inches and sixteenths. To lay off a full-size distance, put the scale down on the paper against the line to be measured. Make a short dash on the paper opposite the zero on the scale and another short dash opposite the division representing the desired distance (Fig. 19). Do not make a dot or punch a hole in the paper.

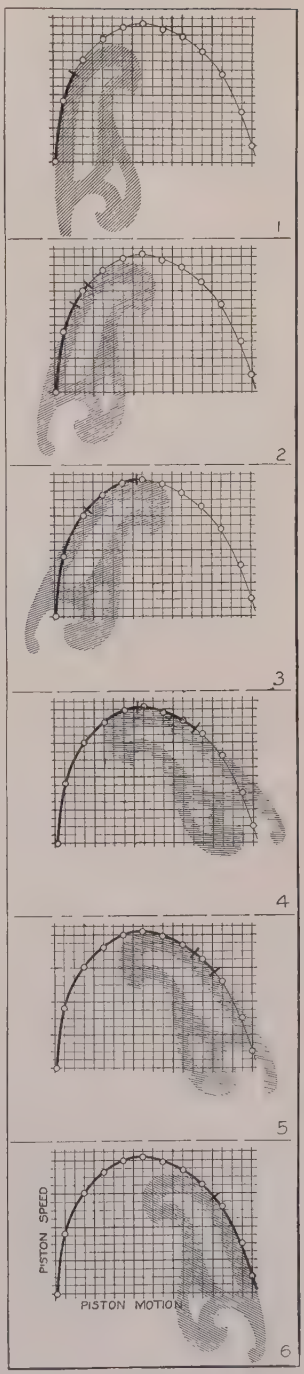


Fig. 17.—Using the curve.

14. Drawing to Scale.—If the object is too large to go on the paper in its full size, it is drawn in reduced proportion. The first reduction is to the scale of 6″ = 1′, commonly called "half

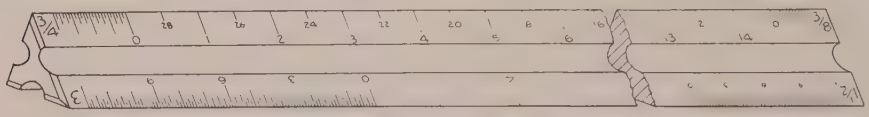


Fig. 18.—Mechanical engineers' (or architects') scale.

Fig. 19.—Making a measurement ($1\frac{7}{16}$″).

size." To measure a distance at the scale of 6″ = 1′, use the full-size scale and consider each half inch as representing an inch, each quarter inch as a half-inch, etc. Thus the 12″ scale will become a 24″ scale. *Example:* To lay off $3\frac{5}{8}$″, start at zero and count three *one-half inches*, and five-eighths of the next half inch, as shown in Fig. 20. *Do not divide the size of the piece by two.*

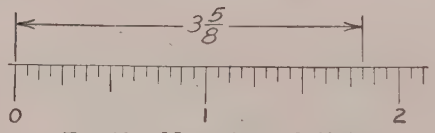


Fig. 20.—Measuring to half size.

If the drawing cannot be made half size, the next scale is 3″ = 1′, often called "quarter size." Find this scale and examine

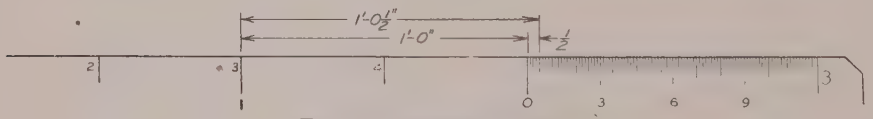


Fig. 21.—Reading the scale.

it. The actual length of three inches becomes one foot, divided into twelve parts, each representing one inch, and these are further divided into eighths. Learn to think of these as real *inches* in *reduced* scale. *Example:* To lay off the distance 1′-0½″ (Fig. 21). Notice the position of the zero mark, placed so that inches are measured in one direction from it and feet in the other, as shown in the figure. Other scales found on a triangular scale are, $1\frac{1}{2}'' = 1'$; $1'' = 1'$; $\frac{3}{4}'' = 1'$; $\frac{1}{2}'' = 1'$; $\frac{3}{8}'' = 1'$; $\frac{1}{4}'' = 1'$; $\frac{3}{16}'' = 1'$; $\frac{1}{8}'' = 1'$; $\frac{3}{32}'' = 1'$.

Take each of these scales in turn, decide what is the longest distance that can be measured in one setting, and what is the smallest division. Measure 2′-5″ with each scale.

15. Spacing.—Dividing lines into spaces and transferring distances is done with the dividers or bow spacers. The dividers are held in the right hand and adjusted as shown at (1) Fig. 22.

The method of dividing a line into three equal parts is shown in Fig. 22. Adjusting the points of the dividers until they appear to be about one-third the length of the line, place one point on one end of the line and the other point on the line as shown at (2). Turn the dividers about the point which rests on the line as at (3), then in the alternate direction as at (4). If the last point falls short of the end of the line, increase the distance between the points of the dividers by an amount estimated to be one-third of the distance *mn*, and start at the beginning of the line again. Several trials may be necessary. If the last point overruns the end of the line, decrease the distance between the points by one-third the extra distance. The bow spacers (Fig. 16 at *A*) are used when working with small distances.

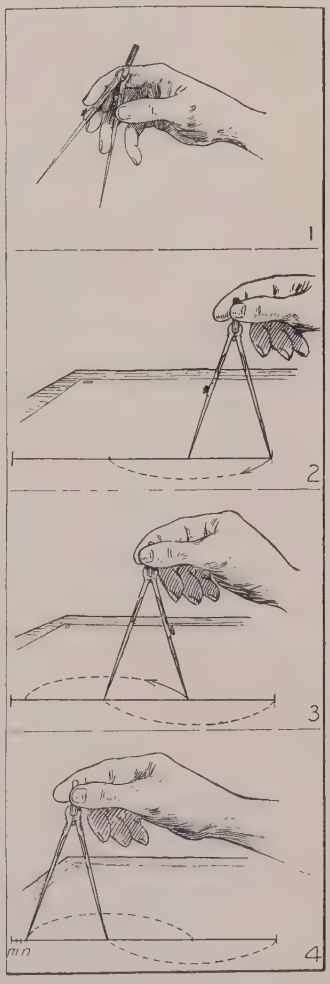


Fig. 22.—Using the dividers.

The dividers should not be used for small distances (of about 1″ or less) as the distance between the points is too easily affected by handling or putting on the drawing board. For accurate work with small distances the bow spacers (Fig. 16 at *A*) should be used, as the distance between the points can be easily maintained once they are set. The method of dividing a line with the bow spacers is the same as described for the dividers. The bow spacers are very useful for many purposes and should receive careful treatment. If the points become dull or bent they should be put into proper condition before being used.

16. It is often convenient to use the scale as a means of dividing a line. If the distance is not easily divisible, the scale may be used as shown in the "movie" of Fig. 23, where (1) shows the line which is to be divided into nine equal parts. Draw a perpendicular line AC through an end of the line as at (2). Apply the scale so

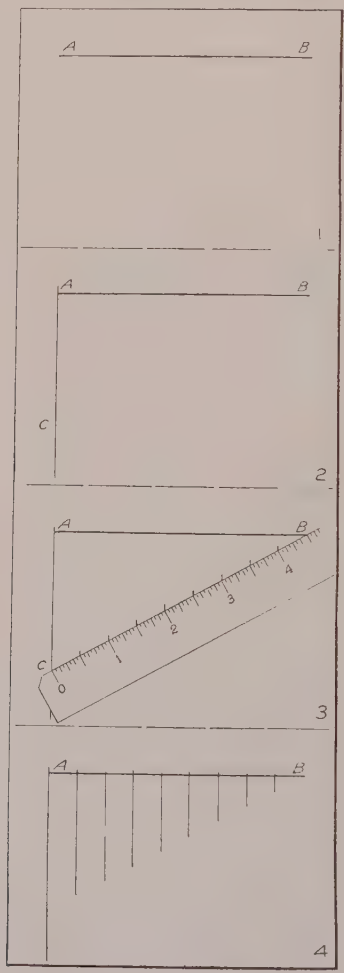


FIG. 23.—Dividing a line.

that nine divisions of the scale (in this case half inches) are included between point B and line AC as shown at (3). Mark opposite each one-half inch and draw vertical lines, which will divide the given line into nine equal parts (4). The geometrical method upon which Fig. 23 is based is given in Art. 151.

CHAPTER III

LETTERING

17. Lettering.—The complete description of any machine or structure requires the use of the *graphical* language to describe shapes and the *written* language to tell sizes, methods of making, kinds of material and other notes. The "written language" as used on drawings is always in the form of LETTERING and not script writing. Simple freehand lettering, perfectly legible and quickly made, is an important part of modern engineering drawings.

18. Various styles of lettering are used in display lettering and printing, each appropriate for a particular purpose. The standard form of letter used on working drawings is the style known as "single-stroke gothic," appropriate because of its legibility and comparative ease of execution. There are two varieties, vertical and inclined. Some concerns use vertical letters entirely, and some use inclined entirely, others use vertical for titles and inclined for dimensions and notes. In the same way, some schools adopt vertical lettering as the standard and some adopt inclined lettering. The young draftsman accepting a position with a company must be able to use the standard of that company. In learning both styles it is better to take up vertical lettering first.

The ability to letter well and rapidly can be acquired only by persistent and careful practice. The form and proportion of each letter must be thoroughly mastered by study and practice and the letters combined into uniformly written, easily read words.

19. Guide lines ruled lightly with a sharp pencil should always be drawn for both tops and bottoms of each line of letters. The clear distance between lines of letters varies from one-half to one and one-half times the height of the capitals. Figure 24 illustrates one method of spacing guide lines when several lines of letters are to be made. Mark the height of the letter on the first line, then set the dividers to the distance wanted between base lines and "step

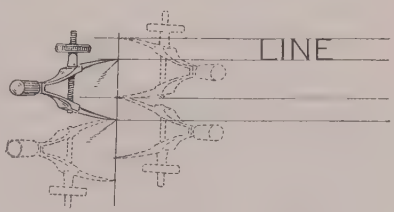


FIG. 24.—Spacing guide lines.

off" the required number of lines. With the same setting step down again from the top point or guide line.

The Braddock-Rowe triangle (Fig. 25) and the Ames lettering instrument (Fig. 26) are timesaving and useful devices for ruling guide lines. Lines are ruled by inserting a sharp pencil point in the holes of the device and moving it back and forth guided by

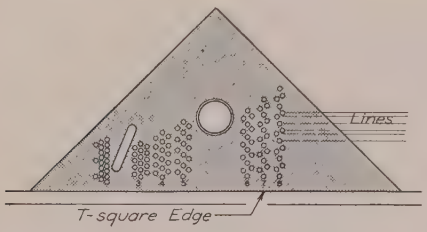


Fig. 25.—Braddock-Rowe triangle.

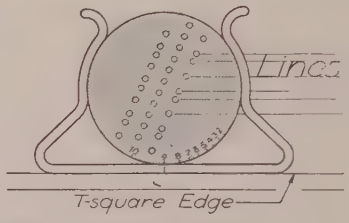


Fig. 26.—Ames lettering instrument.

the T-square edge. Different spacing of groups of holes provides for different sizes of letters, either capital or lower case. The numbers give the heights of capital letters in thirty-seconds of an inch. Thus, No. 4 is one-eighth inch between the top and bottom of the group of three holes.

20. Lettering practice with the pencil and the pen should precede the lettering of words and sentences. Particular attention should be given to numbers and fractions as these form a very important part of every working drawing. The instructions given in Arts. 23 to 27 apply to both pencil and pen lettering.

Fig. 27.—Position for lettering.

21. Pencil Lettering.—The order of strokes and the proportions of the letters should be learned by practice with the pencil before attempting to use pen and ink. Use an F or H pencil sharpened to a long conical point. Learn to use an even pressure and to revolve the pencil in the fingers after every few strokes. The pencil should be held just firmly enough to control the strokes.

The constantly increasing use of pencil tracings in commercial drafting rooms makes the ability to do good pencil lettering a necessary part of the draftsman's qualifications.

22. Pen Lettering.—The term "single stroke" means that the width of the stem of the letter is the width of the stroke of the pen. A pen for single-stroke lettering must therefore make the required width of line in any direction without pressure enough to spread the nibs. For large letters (¼" high) Esterbrook's 802 or Hunt's 512, which are ball-pointed pens, are among those desirable. For ordinary dimensions and notes Esterbrook's 819 or Gillott's 404 are satisfactory. (Do not use a ruling pen for freehand lettering.) The pen should be held in the position shown in Fig. 27, the strokes drawn with a steady even motion of the fingers and a slight uniform pressure, not enough to spread the nibs of the pen.

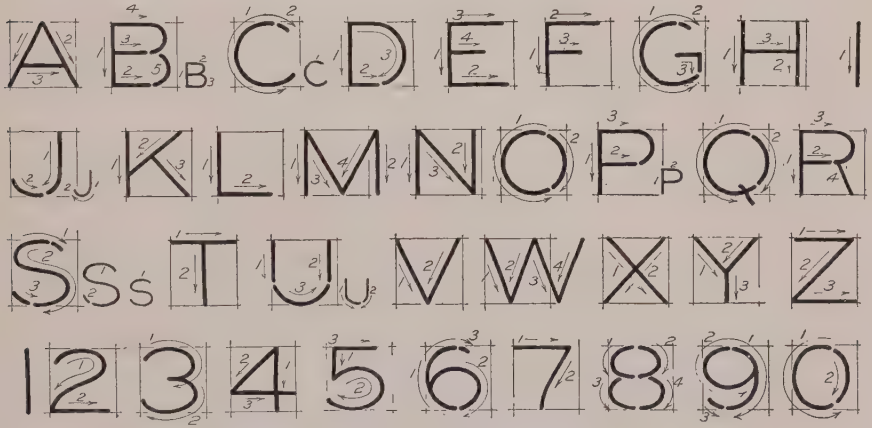


FIG. 28.—Single-stroke vertical capitals.

23. Single-stroke Vertical Capitals.—An alphabet of vertical capitals is shown in Fig. 28. Each letter is shown in a square, so that the proportions of its width to height may be easily learned. Observe that the *T*, *Z*, *X*, *A*, *O*, *Q* fill the square, whereas the *H*, *L*, *E*, *F*, *N*, etc., are narrower, and the *M* and *W* wider, than their height.

In learning to letter the first step is to learn the shapes and proportions of the individual letters and the order in which the strokes are made. The arrows and numbers on the letters give the order and direction of strokes. Vertical strokes are always made downward and horizontal strokes from left to right.

Special care and practice must be given to the numerals. Notice that the shapes of the numbers are just as different from those used in ordinary figuring as the letters are from ordinary writing. Particularly is this true of the 2, 4, 6, 8 and 9. Fractions

(Fig. 29) are always made with a horizontal division line, with figures two-thirds the height of the whole numbers and with a clear space above and below the division line.

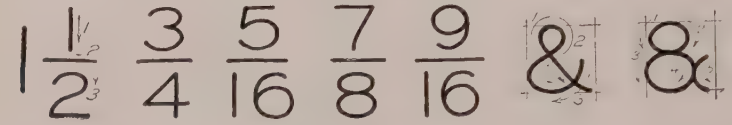


Fig. 29.—Fractions.

24. Single-stroke Vertical Lower Case.—Vertical lettering on working drawings is generally done in all capitals. Vertical lower case, however, is used in map drawing and for various other purposes (Fig. 30). The letters are usually made with bodies two-thirds the height of the capitals with the ascenders (*b*, *d*, *f*, etc.) extending up to the cap line and the descenders (*g*, *j*, *p*, etc.) dropping the same distance below. They are based on the combination of circle and straight line (Fig. 31). The "monogram" in the figure contains eighteen of the twenty-six letters.

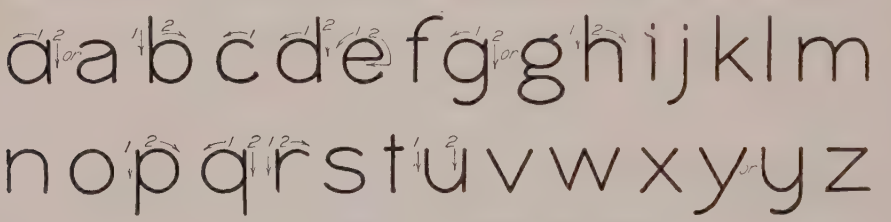


Fig. 30.—Single-stroke vertical lower case.

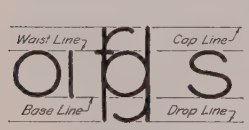


Fig. 31.

25. Single-stroke Inclined Capitals.—In making inclined letters there are two things to watch: first, to keep uniform slope and second, to get the correct shape of the curves of the rounded letters.

Slanting "direction lines" should be drawn with a lettering triangle (of about 67½°) or by setting a slope of 2 to 5 by marking two units on a horizontal line and five on a vertical line, and using the T-square and triangle as shown in Fig. 32. The form taken by the rounded letters when inclined is illustrated in Fig. 33, showing that the curves are sharp in the upper right-hand and lower left-hand corners and flattened in the other two corners.

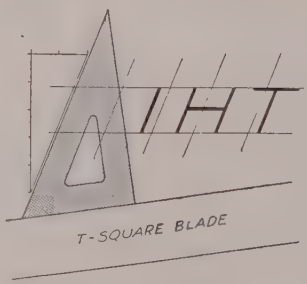


Fig. 32.—Direction lines.

The letters *H*, *A*, *V* and *W* are shown with direction lines in Fig. 34. Note particularly that the lines of *A*, *V* and *W* make equal angles on each side of the center line.

FIG. 33.

FIG. 34.

The alphabet and numerals with order and direction of strokes are given in Fig. 35.

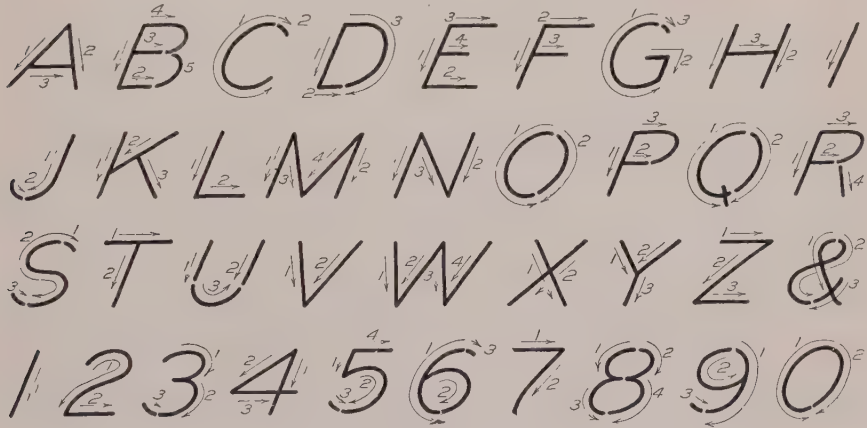


FIG. 35.—Single-stroke inclined capitals.

26. Single-stroke Inclined Lower Case.—This letter, sometimes called the "Reinhardt letter," is in general use for notes on drawings as it is very legible and effective and can be made very rapidly. The bodies are two-thirds the height of the capitals, with the ascenders extending to the cap line and the descenders dropping the same distance below the base line.

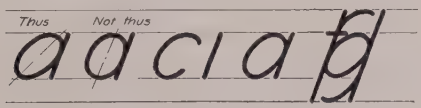


FIG. 36.

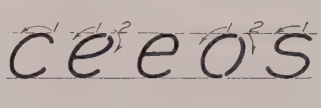


FIG. 37.

For study the letters may be divided into four groups:

Group I: *ijkltvwxyz*	Group III: *hmnruy*
Group II: *abdfgpq*	Group IV: *ceos*

Group I contains the straight-line letters. Keep the slope uniform by following "direction lines" penciled lightly on the sheet. Be particularly careful about the slant of the angle letters

v, w, x, y and have their sides make equal angles with the sloping center line.

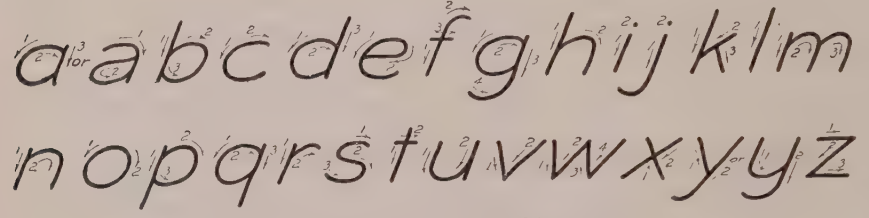


Fig. 38.—Single-stroke inclined lower case.

The letters of Group II are made up of a partial ellipse whose major axis slants 45° and an inclined straight line (Fig. 36). The hook letters of Group III are made with a part of the same ellipse. The letters of Group IV are made with the same shape of ellipse as the capitals (Fig. 37). The alphabet, with order and direction of strokes, is given in Fig. 38.

LETTERING COMPOSITION
INVOLVES THE SPACING OF LETTERS
WORDS AND LINES AND THE CHOICE
OF APPROPRIATE STYLES AND SIZES

Fig. 39.—An example of spacing.

27. Composition.—Composition in lettering means the arrangement and spacing of words and lines, using letters of appropriate style and size. After the shapes of the separate letters have been mastered, all practice work should be on words and sentences, and the keynote of success is *uniformity*. Uniform height is obtained by having each letter meet top and bottom guide lines; uniform weight by making all strokes of the same thickness; uniform direction by drawing and following direction lines either vertical or inclined; and uniform color by careful spacing.

28. Letters in words are not put at equal distances from each other but are spaced so that the areas of white spaces included between the letters are approximately equal, thus making them appear to be spaced uniformly. Thus two adjacent letters with straight sides would be spaced much further apart than two curved letters. Note the variation in spacing in the word "lettering" in Fig. 39. In general, keep letters in words fairly close together. In spacing words the clear distance between them should not be more than the height of the letters. There are many variations

in letters such as extending or compressing the letters (Fig. 40). In such cases all the letters must be extended or compressed in proportion.

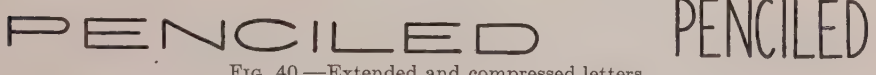


Fig. 40.—Extended and compressed letters.

For contents and composition of titles see Art. 84.

29. For all ordinary working drawings the single-stroke letters as given in this chapter are sufficient. Larger sizes than one-fourth inch may be made in single stroke with special lettering pens such as the Speedball, Drawlet or Payzant. Sometimes, however, one may be called upon to draw letters for some other purpose.

Fig. 41.—Commercial gothic alphabet.

Such letters as the commercial gothic of Fig. 41, may be drawn either freehand or, if rather large, with instruments and filled in with a brush. An alphabet of Roman letters is shown in Fig. 309 of Chap. XVI. A single-stroke letter based upon the Roman is generally used on architectural drawings (Fig. 310, Chap. XVI).

CHAPTER IV

THEORY OF SHAPE DESCRIPTION

30. There are two things that a designer, inventor or builder must be able to do: First, he must be able to *visualize* or to see clearly in his mind's eye what an object looks like without actually having the object; second, he must be able to describe it so that it could be built. A few lines properly drawn on paper will describe an object more accurately and clearly than a picture or a written description. Ability to describe the true shape of an object by means of lines and to be able to read and understand such descriptions requires a thorough knowledge of the theory upon which this method is based.

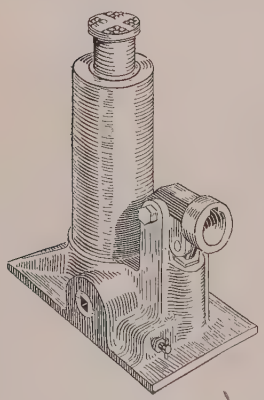


FIG. 42.

31. Describing Objects by Views.—For the graphical description of an object we have available the paper, pencil and instruments explained in Chap. II. On the paper we can make measurements in a single plane only, while all objects have dimensions perpendicular to the paper as well as parallel to it. A picture can be made which would show, just as a photograph would, the general appearance of the object, but it would not show the *exact* forms and relations of the parts of the object. It would show it as it *appears* and not as it really is.

Our problem then is to represent solid objects on a sheet of paper in such a manner as to tell the exact shape. This is done by drawing a system of **views** of the object as seen from different positions, and arranging these views in a definite manner.

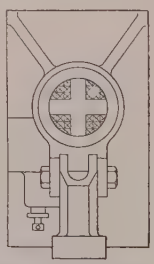


FIG. 43.—Top view.

A picture of an hydraulic jack for an automobile (Fig. 42) shows this tool as it ordinarily appears to us, but it does not show the true shapes of the parts. The top of the cylinder appears as an ellipse, although we know it really is circular. If we look down at the jack from

above, we obtain a *view*, showing the exact shape of the cylinder or stem, and the outline of the other parts as seen from above. This is called a *top view* or plan (Fig. 43). This view does not tell us the height of the jack, so it is necessary to take another view from a position directly in front or else from the left or right side. In this way either a *front view* or *side view*, to show the height, is added. Often, as in this case, both the front and side

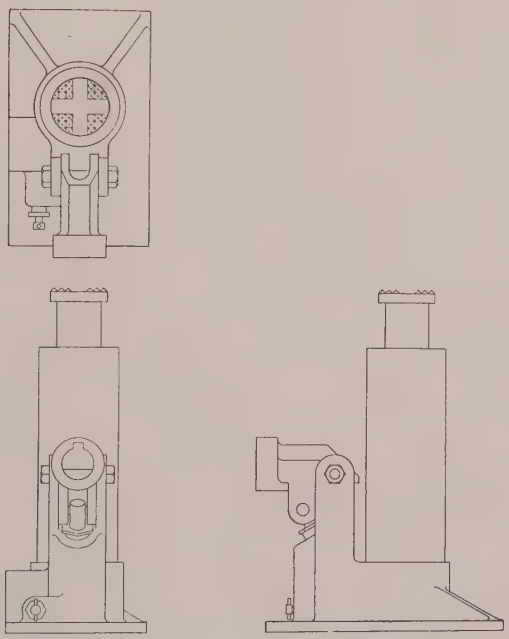


FIG. 44.—Top, front, and right-side views.

views, in addition to the top view, are needed to describe the object (Fig. 44).

Since the top of the cylinder or stem is level, it will show as a straight line in the front and side views. The base shows as a rectangle in the top view, but the bottom of the base appears as a straight line in the front and side views. Notice the cylinder and hole for the lever rod which appear as circles in the front view but as straight lines in the side and top views.

The three views taken together completely define the shapes of all visible parts of the jack and their exact relations to each other.

It is evident that the front and side views are exactly the same height. When drawn, they are placed directly across from each

other. The top view is placed directly above the front view, and the three views together appear as in Fig. 44.

Sometimes a left-side view describes the object or construction more clearly than the right-side view and in such cases it should be used. Figure 45 shows the top, front and left-side views of the jack. Notice that it shows the boss and plug which cannot be seen in the right-side view. For some objects it may be neces-

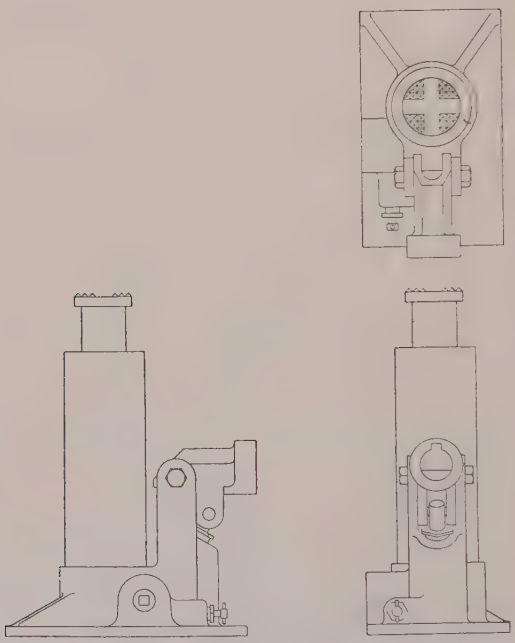


Fig. 45.—Top, front, and left-side views.

sary to show both the right- and left-side views in order to provide a complete description of the object.

Notice the positions of the different views in relation to each other. In Figs. 44 and 45 it will be observed that the lever rod opening is toward the front in the top views. Note that it is also toward the front view in both the right- and left-side views.

As a further explanation of the relation of the three views, study the drawing of the chair shown in Fig. 46. Notice that the magazine holder is at the right in the top and front views and therefore shows in the right-side view. The front of the chair is toward the front view in the top and two side views.

32. Theory of the Relation of Views.—The principle of representing an object by different views, as just described, is called *orthographic projection* and is the basis of all kinds of industrial drawing. The real theory of orthographic projection must be well

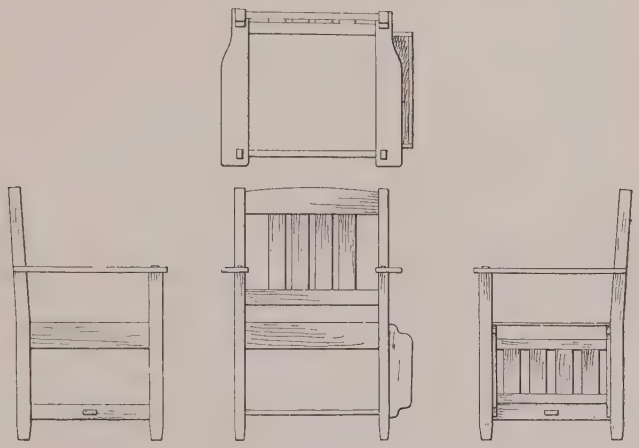


FIG. 46.—Relation of views.

understood before complicated or difficult drawings can be made or read.

The following definition has been given: "*Orthographic projection is the method of representing the exact form of an object in two or more views on planes generally at right angles to each other, by dropping perpendiculars from the object to the planes.*"

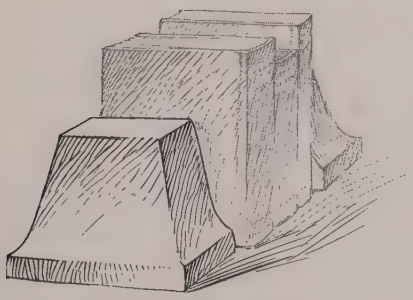


FIG. 47.—Book end.

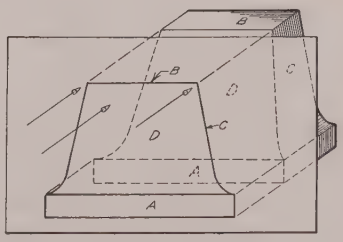


FIG. 48.—The vertical plane.

Suppose the book end shown in Fig. 47 is to be represented. The draftsman imagines himself to be looking through a transparent plane set up in front of the object (Fig. 48). If from every point of the object perpendiculars be imagined as extended or

projected to the plane, the result on the front of the plane would be the *projection* on the plane, called the *vertical projection* or *front view*, or in architectural drawing the *front elevation*, and would show the true height and length of the object.

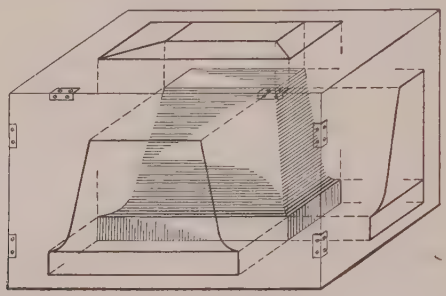


Fig. 49.—The glass box.

Suppose now that a horizontal plane is hinged at right angles to the first plane, the observer looking through it at the top of the object (Fig. 49). Perpendiculars from the object to this plane will give the *horizontal projection*, or *top view*, or, as called in architectural drawing, the *plan*. This view will show the width of the object from front to back, as well as the length already shown

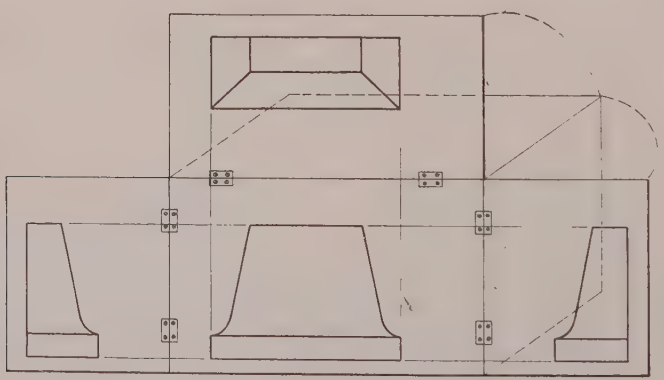


Fig. 50.—The box opened.

on the front view. These two planes represent the drawing paper, and, if the horizontal plane be imagined as swung up on the hinges until it lies in the extension of the front plane, the two views will be shown in their correct relationship as they would be drawn on the paper and together give the length, breadth and height. This explains the reason for the statement made in the

preceding section, that the top view is always drawn directly over the front view.

The *side view* or *side elevation* is imagined as made on a plane perpendicular to both top and front planes. Thus the object

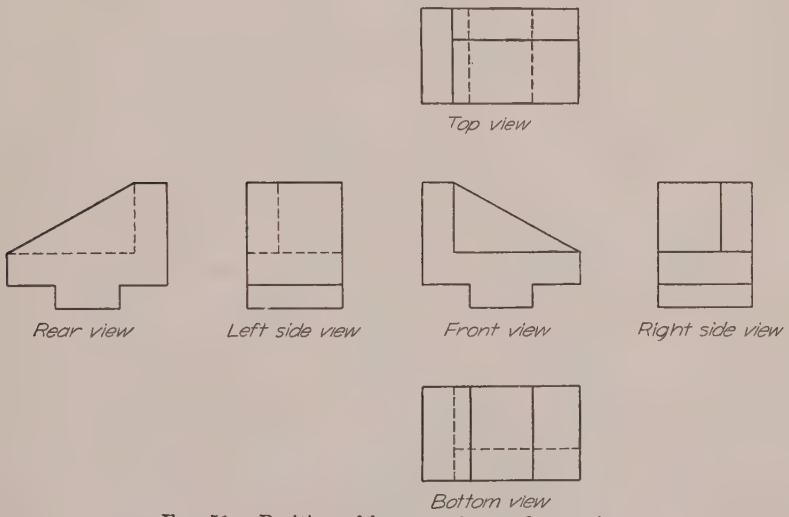


FIG. 51.—Position of bottom view and rear view.

may be thought of as being inside a glass box or show case, as in Fig. 49. The projections on the sides of this box would be the *views*, which we have discussed, and when these sides are opened

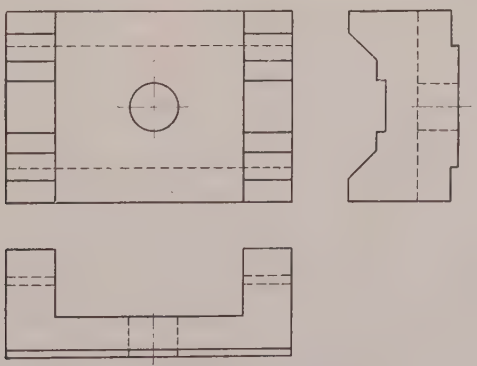


FIG. 52.—Second position of side view.

up into one plane, the views take their relative positions as on the paper with the top view directly over the front view and the side views directly across from the front view (Fig. 50).

33. Arrangements of Views.—It is sometimes desirable or necessary to show the rear or bottom views of an object. In such cases glass planes can be placed in back of and below the object, thus completing the box. Views can then be projected to all six faces or planes of the box. When the faces of the box are opened up into one plane, the views will show as in Fig. 51, which illustrates the American Standard arrangement of the six views.

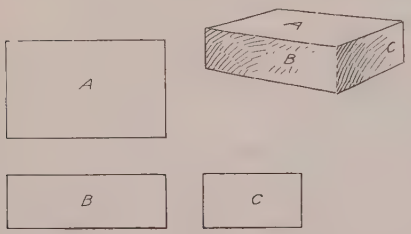


FIG. 53.

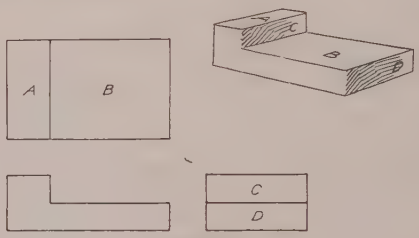


FIG. 54.

The proportions of an object or the size of the sheet sometimes make it desirable to show a side view in the "second position" or directly across from the top view as in Fig. 52, which illustrates the second position for the right-side view.

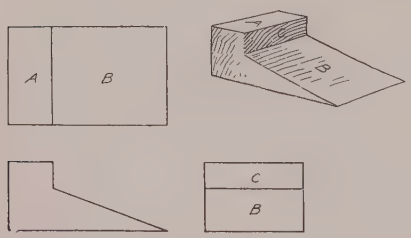


FIG. 55.

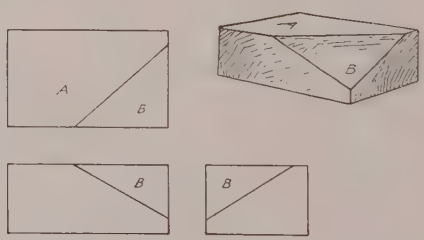


FIG. 56.

34. Principles.—From a study of these projections the following principles will be noted:

1. A face parallel to a plane of projection is shown in its true size, as *A* on the front view (Fig. 48).

2. A face perpendicular to a plane of projection is projected as a line, as *B* and *C* (Fig. 48).

3. A surface inclined to a plane of projection appears foreshortened, as *B* (Fig. 55).

4. Similarly, a line parallel to a plane of projection will show in its true length.

5. A line perpendicular to a plane of projection will be projected as a point.

6. An inclined line will have a projection shorter than its true length.

35. Studies.—As a further explanation of how the theory of projection is applied, study the drawings of the objects in the following figures. In Fig. 53 each view represents a single surface. In Fig. 54 the top view shows two surfaces A and B at different levels, and, as shown by the front view, surface A is above surface B. In the side view the surfaces C and D are shown. In Fig. 55

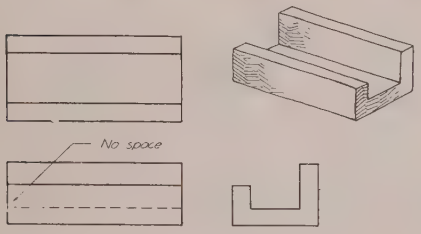


FIG. 57.

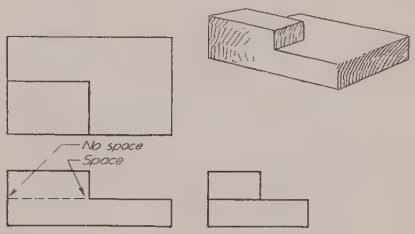


FIG. 58.

the surface B is inclined and shows slightly foreshortened in the top view and very much foreshortened in the side view. To obtain the true size of the surface B, its length must be taken from the front view and its width from the top or side view. A surface which is inclined in three ways is illustrated in Fig. 56 where the corner of the block has been cut away. The true size of the surface B (Fig. 56) does not show in any of the views.

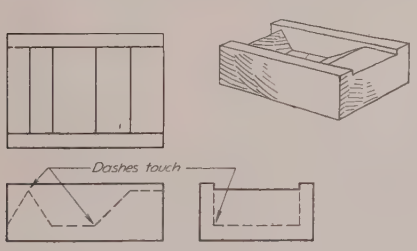


FIG. 59.

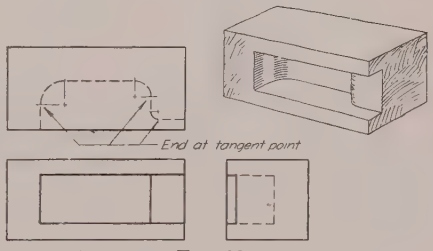


FIG. 60.

36. Hidden Lines.—Since it is necessary to describe every part of an object, all surfaces must be represented whether they can actually be seen or not. To distinguish surfaces which cannot be seen in the views, the surfaces are represented by *hidden* lines composed of short dashes as in Figs. 57, 58, 59 and 60. Notice that the first dash of a hidden line touches the line at which it starts (no space), that dashes touch at corners, but that, if a hidden line is a continuation of a full line, a space is left between the full line and the first dash of the hidden line. Notice in Fig. 60 that the dashes for hidden arcs start and end at the tangent points.

37. Curved Surfaces.—The fact that some curved surfaces such as cylinders and cones do not show as curves in all views is illustrated in Figs. 61, 62 and 63. A cylinder appears as a circle in one view and as a rectangle in the others, as in Fig. 61, which shows three views of a cylinder when placed in different positions. A cone appears as a circle in one view and as a triangle in the others, as at *C* in Fig. 62.

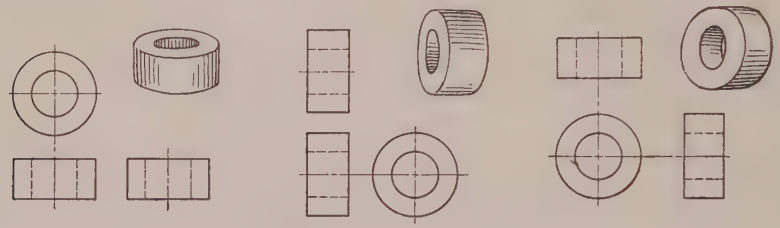


FIG. 61.—Views of cylinder.

The lathe center and the rivet head at 1 and 2 of Fig. 64 are made up of cylinders, cones and frustums of cones. These are *single curved surfaces* and are represented by circles in one view and straight lines in the other. The handles at 3 and 4 and 5 have *double curved surfaces* which are represented by curves in both views. The ball handle at 5 has spherical ends and both views are circles, because a sphere appears as a circle when viewed in any direction.

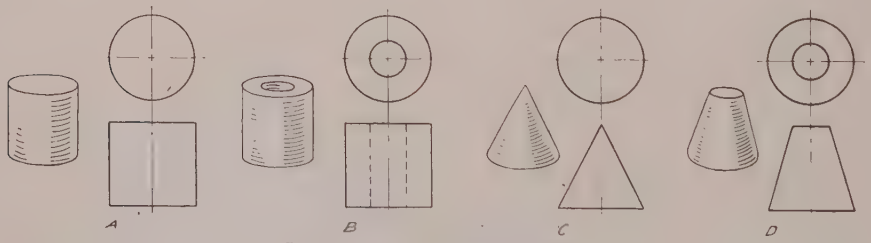


FIG. 62.—Cylinders and cones.

The bearing shown in Fig. 65 is made up of flat and curved surfaces which require visible and hidden lines. Note that surface *A* of the side view is shown by a full line *ab* in the front view and by a hidden line *ac* in the top view. Compare the three views with the picture and notice how the various parts are described in the different views. Study the reason for using full or hidden lines in each case as well as the necessity for three views to give a complete

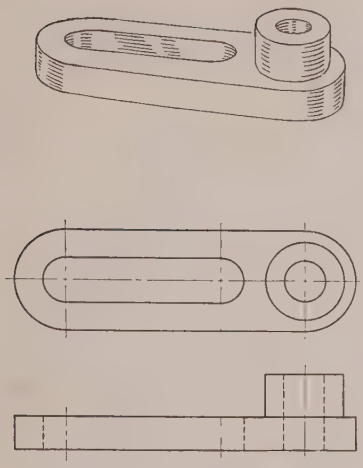


FIG. 63.—Curved surfaces.

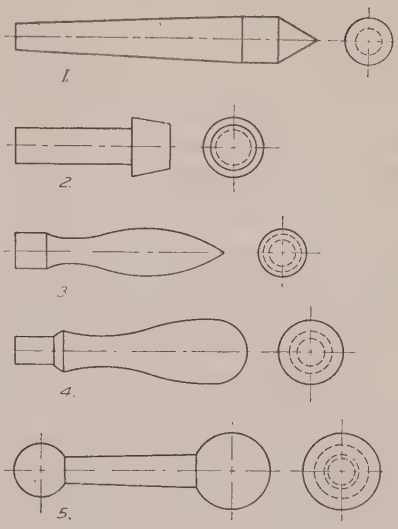
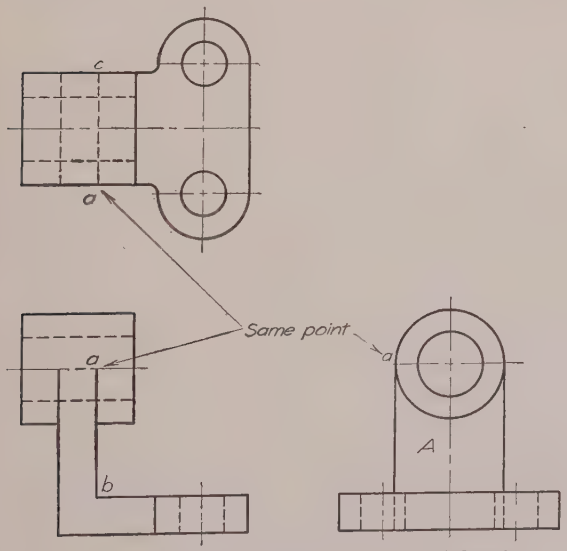


FIG. 64.—Curved surfaces.

description of the bearing. Considering the views shown to be the top, front and right-side views, try to see how the bottom, rear and left-side views would appear and which lines would be visible



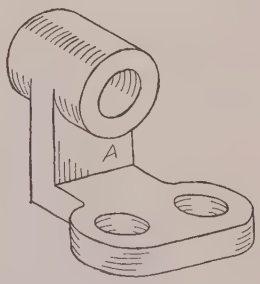


FIG. 65.—A bearing.

and which ones would be hidden. For a casting the working drawing would show fillets or "rounded in" corners at *b* and between the cylinder and vertical support. Fillets are omitted in Fig. 65

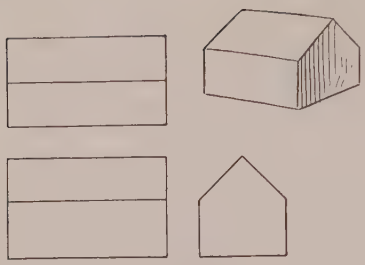


FIG. 66.

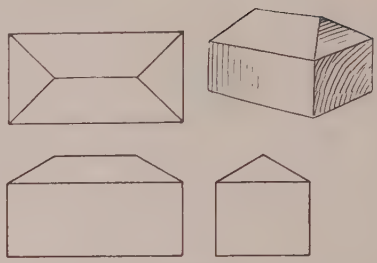


FIG. 67.

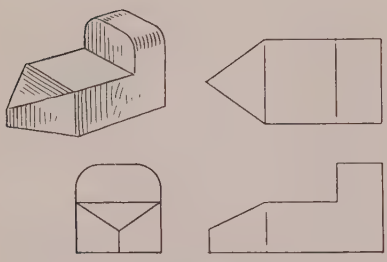


FIG. 68.

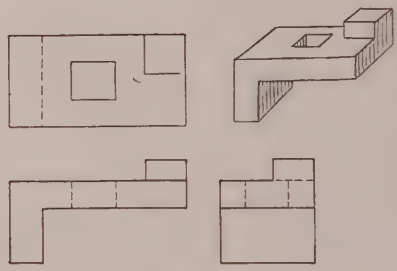


FIG. 69.

to simplify the views for study purposes and to show how point *a* in the front view is determined by the tangent point in the right-side view.

Pictures and drawings of several objects are given in Figs. 66 to 69 for study and comparison. Consider the reason for the views which have been selected and the purpose of each line on the views. Could any of the views be omitted for any of the objects? Notice how the inclined surfaces are represented and that the views do not show the true sizes of such surfaces.

CHAPTER V

SKETCHING

38. Freehand drawing or sketching is a convenient and valuable means of shape description in the practice of engineering as well as in the study of view drawing.

Accuracy of observation and sureness in the handling of the pencil are necessary requirements for making good sketches.

An F or H pencil, sharpened to a long conical point, an eraser and suitable paper comprise the necessary sketching equipment. "Squared" paper is sometimes used, but plain paper is suggested for beginning practice.

39. Straight Lines and Curves.—Views are made up of straight lines and curves so the student should become proficient in these elements before sketching an object.

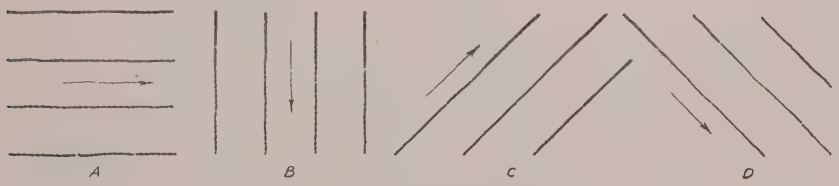


FIG. 70.—Sketching straight lines.

Horizontal lines are sketched from left to right, as at *A* in Fig. 70, and vertical lines downward, as at *B*.

Methods of sketching circles are shown in Fig. 71. At *A* and *B* radii are estimated and marked off on vertical and horizontal center lines to locate a square in which the circle is sketched. At

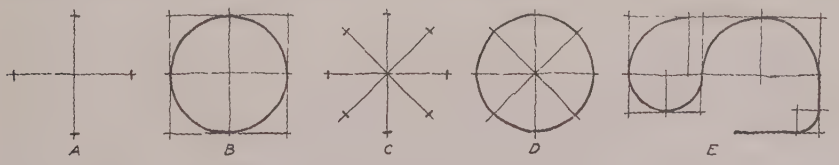


FIG. 71.—Sketching circles and curves.

C and *D* radii are estimated and marked off on the lines as indicated to locate points through which the circle is sketched. Arcs, tangent arcs and curves are conveniently sketched by blocking in with straight lines.

40. Making a Sketch.—The stages in making a sketch are shown in Fig. 72. Observe the object, pictured at (1), select the views necessary to describe its shape and judge the proportions. Estimate the proportions carefully and mark off distances for the three views as at (2). Block in the enclosing rectangles for the views as at (3). Locate the details in each of the views and block them in as at (4). Finish the sketch by brightening up the lines as at (5). The preliminary blocking-in lines should be drawn so light that they will not have to be erased and so that the dashes for hidden lines can be drawn over them.

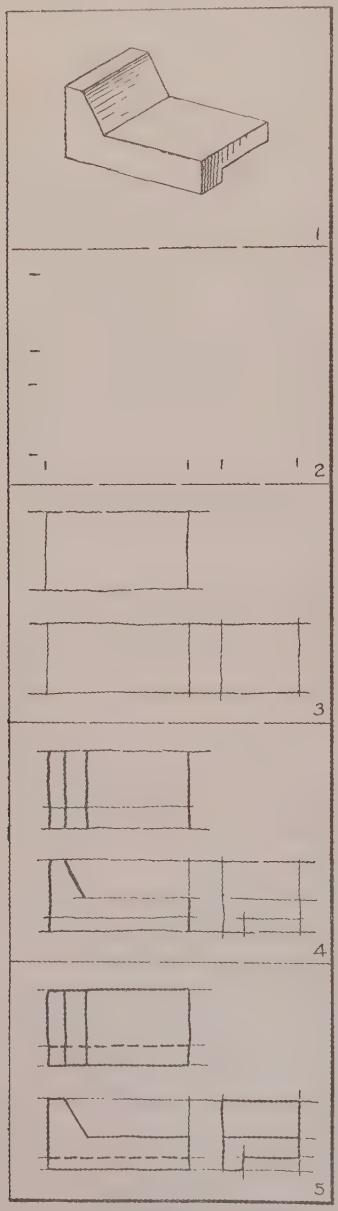


FIG. 72.—Stages in making a sketch.

A picture of a V-block is shown in Fig. 73. In Fig. 74, the views necessary to describe the shape of the V-block have been sketched freehand. Notice how the proportions have been observed and how the blocking-in lines have been sketched in for all the views so that they are properly located in the available space. Never attempt to sketch or complete one view at a time, but block them all in, and then proceed to work up the corresponding details in all of the views.

41. Freehand Studies.—Line exercises are given in Fig. 75 for preliminary practice. All distances mentioned and angles indicated are to be estimated. Exercises *A*, *B*, *C* and *D* may be sketched in 2″ or 3″ squares with the parallel lines equally spaced. Exercises *E*, *F*, *G* and *H* may be sketched in rectangles 2″ × 4¼″ or 3″ × 6⅜″. Exercises *I*, *J*, *K*, *L*, *M* and *N* may have a radius of 1″ or 1½″ for the largest circles. The proportions should be observed very carefully and the blocking-in lines should be located as accurately as possible by eye.

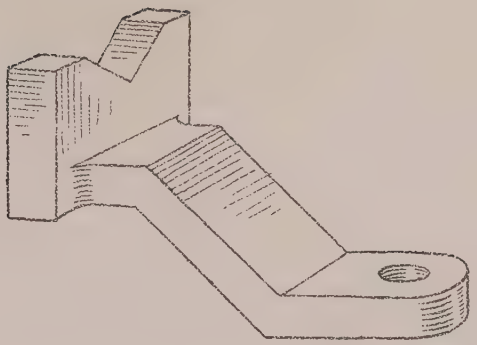


FIG. 73.—An object to be sketched.

The objects shown in Figs. 76 to 79 are designed to give the student practice in shape description by freehand sketching either in pencil on plain or squared paper or on the blackboard. The sketches should be made large enough to give a clear description of the shape of the object. Consider the proportions of the object and the choice of views necessary for a complete description. Block in the views and brighten the result as in Fig. 74.

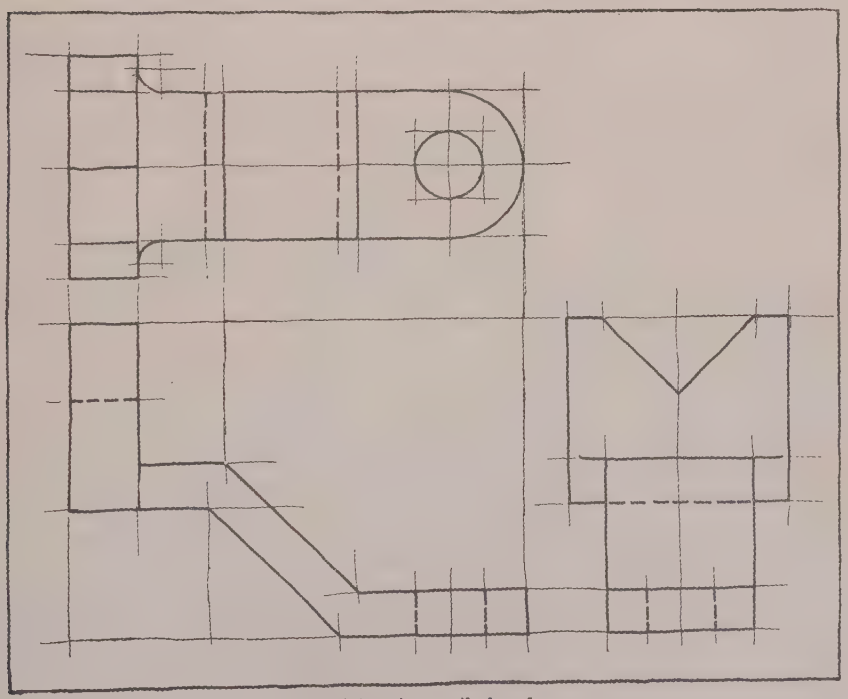


FIG. 74.—A pencil sketch.

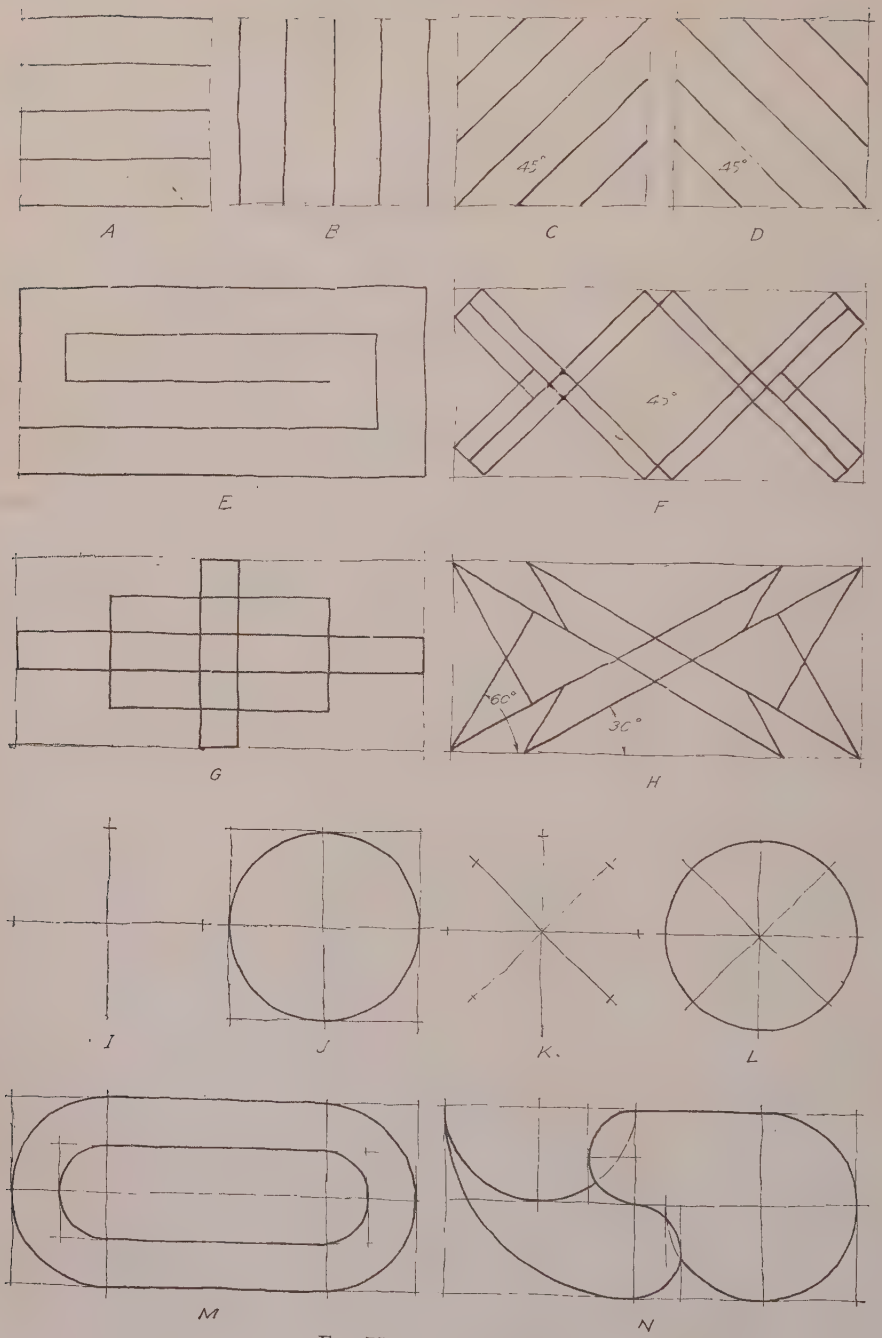


FIG. 75.—Line exercises.

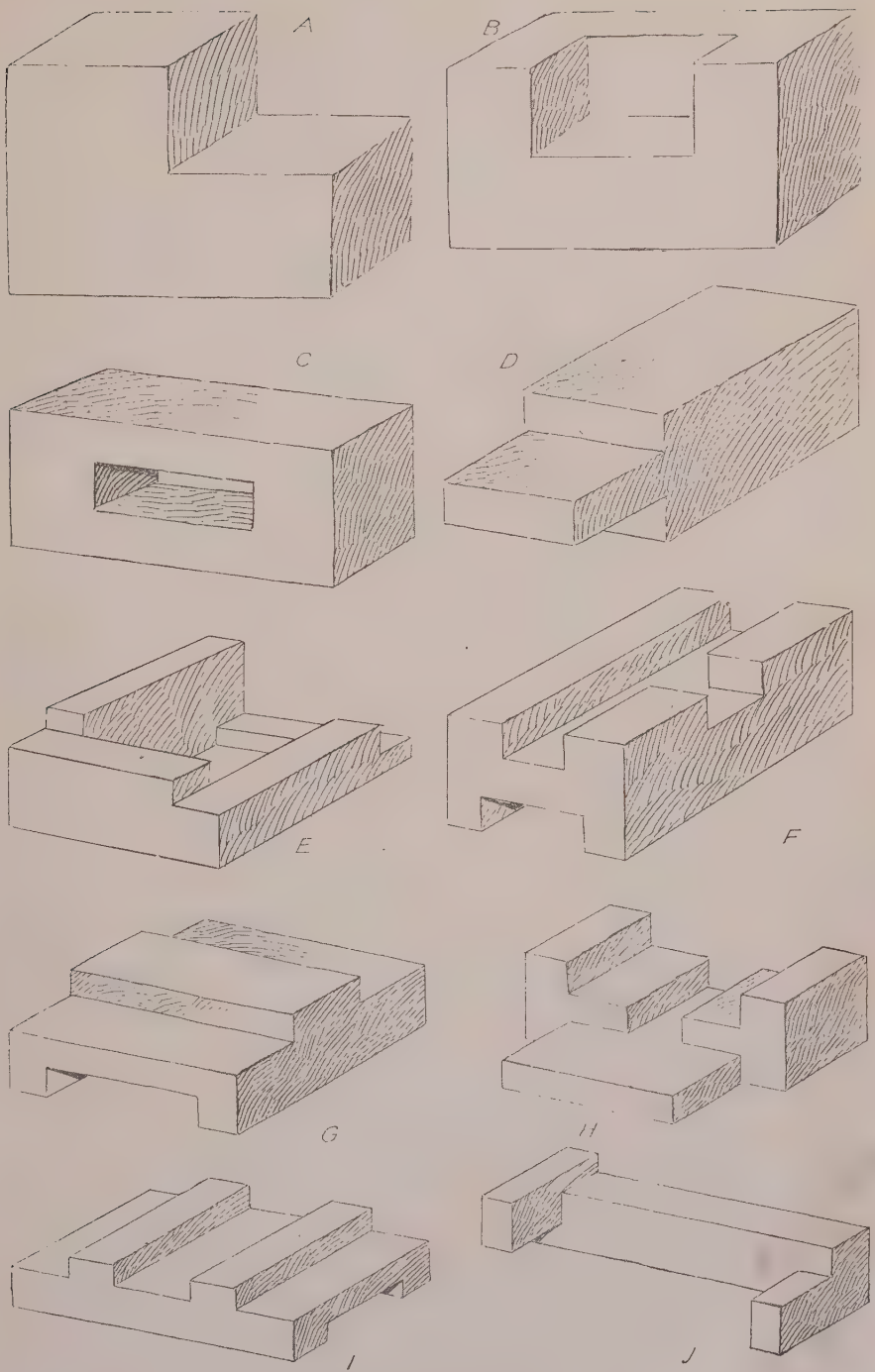


Fig. 76.—Problems for freehand sketching.

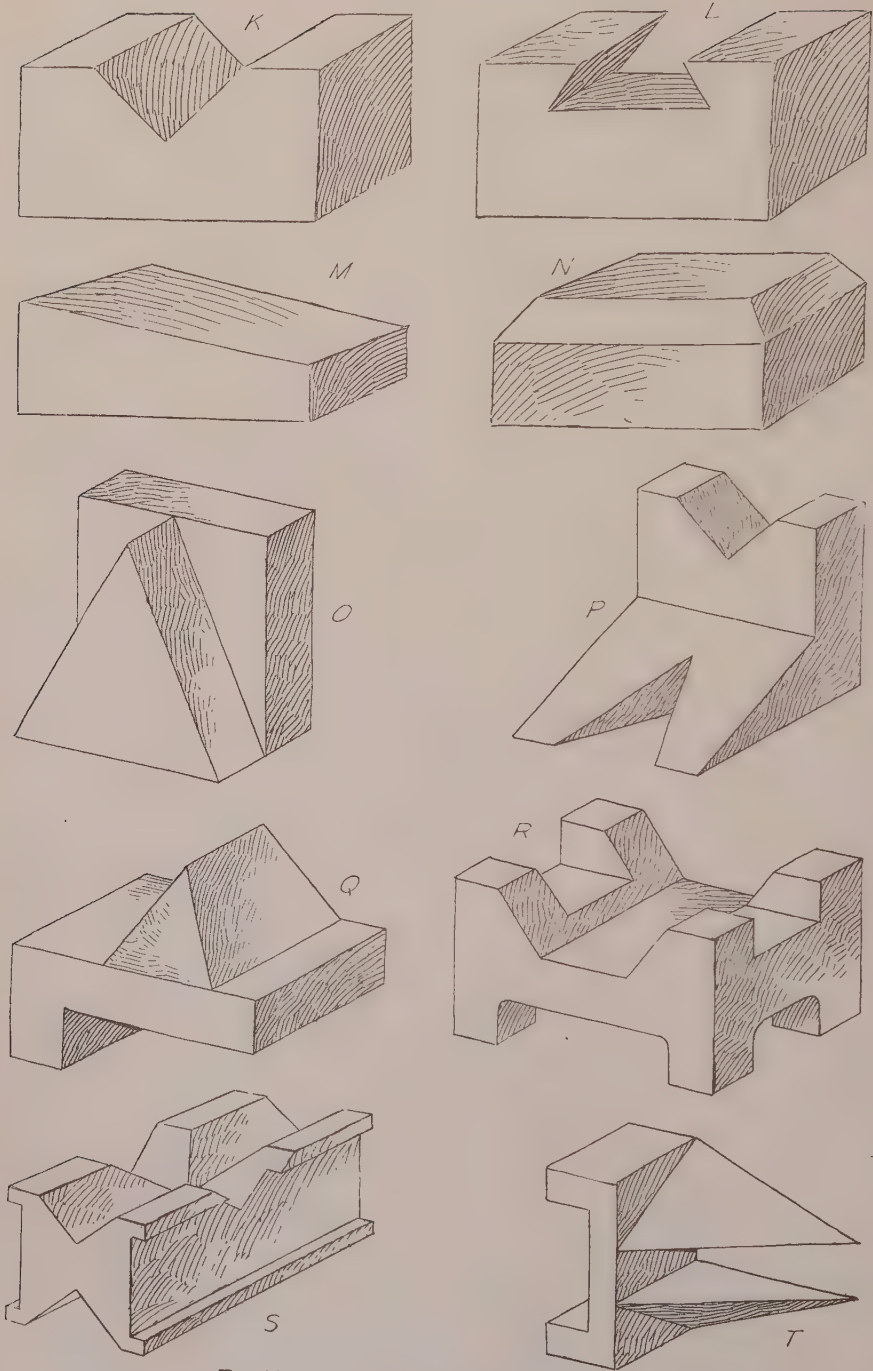


Fig. 77.—Problems for freehand sketching.

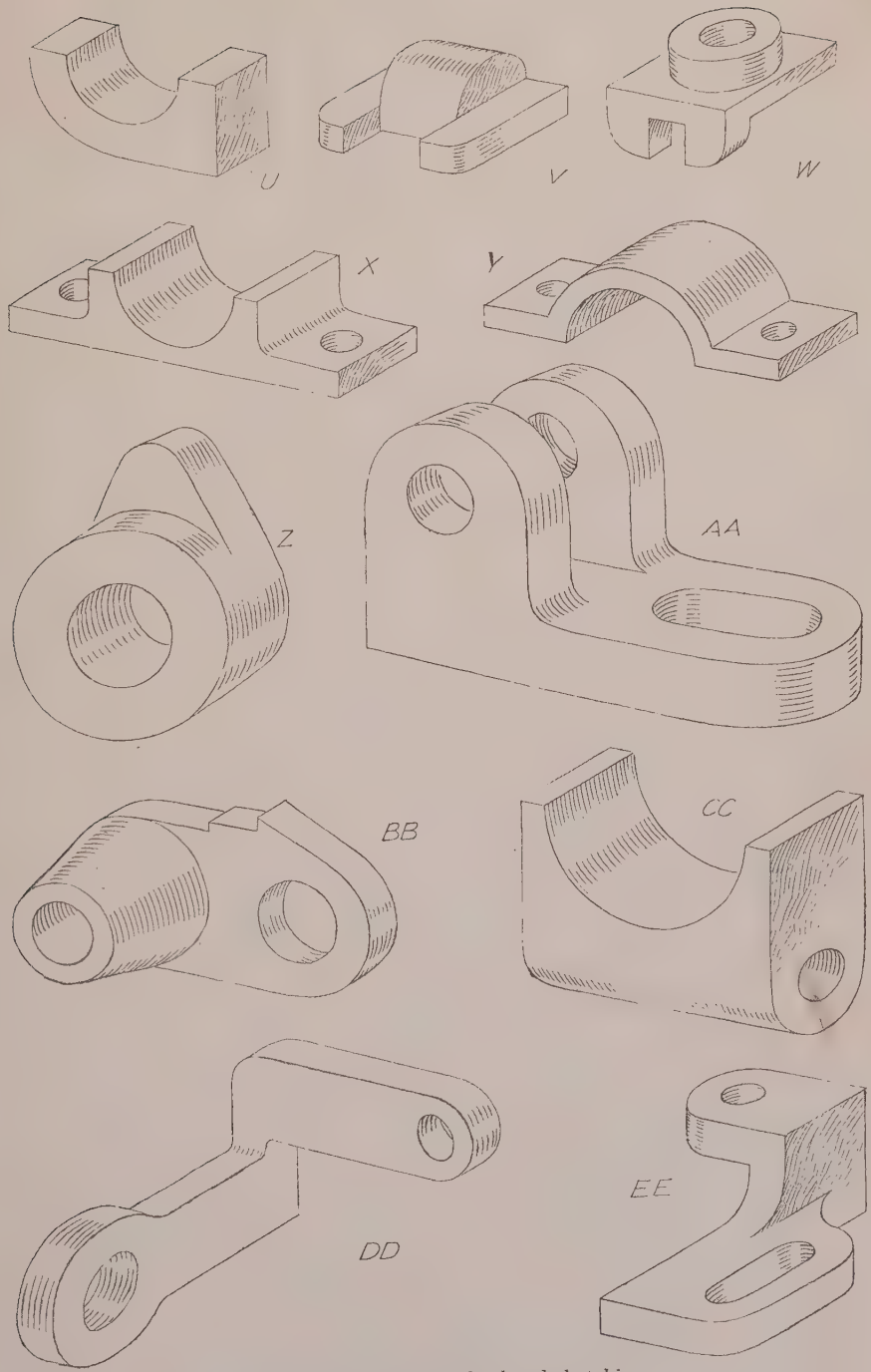


FIG. 78.—Problems for freehand sketching.

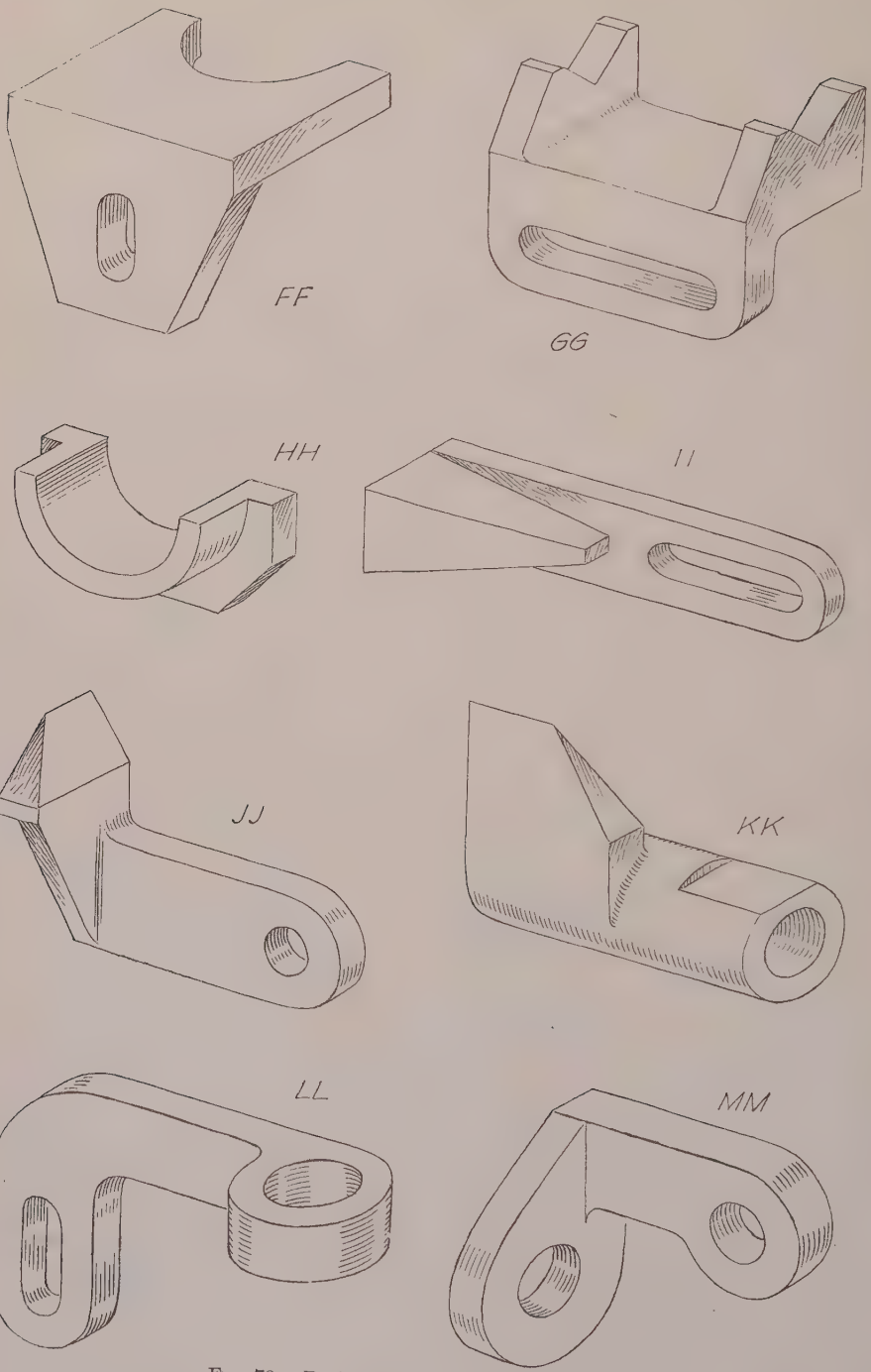


Fig. 79.—Problems for freehand sketching.

CHAPTER VI

SECTIONS

42. We have learned that the parts of an object that cannot be seen are represented by hidden lines (composed of short dashes). This method is satisfactory where the object is solid or the interior simple. There are many cases, especially where there is considerable interior detail or where several pieces are shown together, in which the hidden lines become confusing or hard to read. This difficulty is avoided by using a *sectional view.*

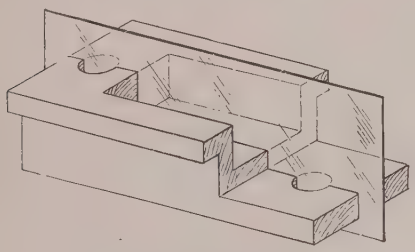


FIG. 80.—Cutting plane.

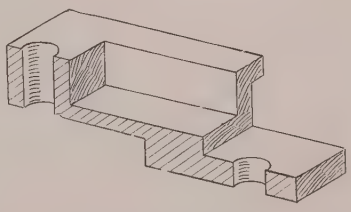


FIG. 81.—The cut surface.

43. A sectional view is obtained by supposing the piece to be cut apart by an imaginary cutting plane, and the front part removed, thus exposing the interior. This is shown in pictorial form in Figs. 80 and 81. Full views are shown in Fig. 82, and a sectional view is shown in Fig. 83.

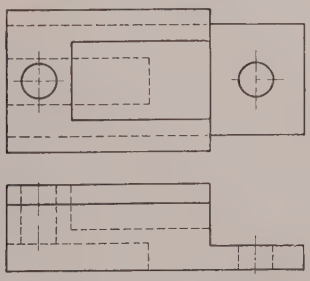


FIG. 82.—Exterior views.

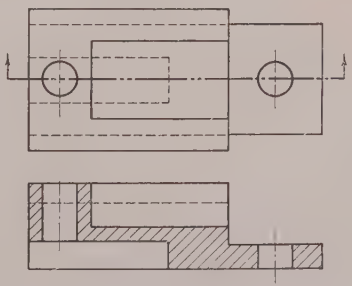


FIG. 83.—Sectional view.

The imaginary cutting plane is shown in Fig. 80 and the appearance of the cut surface, after removing the front portion, in Fig. 81. On a drawing the cut surface is represented by section lining

with uniformly spaced fine lines generally at 45° (Fig. 83). In the top view the edge of the cutting plane is indicated by a line (see alphabet of lines, Fig. 141), but the part supposed to be cut away is not left out.

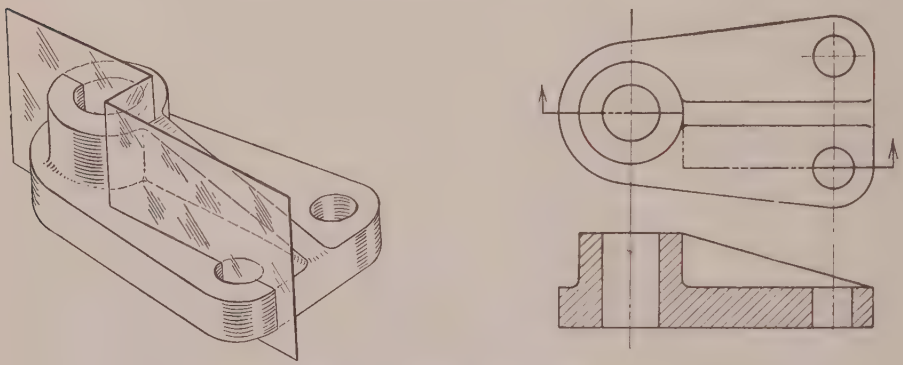


Fig. 84.—Offset cutting plane.

44. A full section is a view as the object would appear if cut entirely across, as in Fig. 83. The cutting plane is usually taken straight through on the main axis, but it may be offset in any part of its length to go through some detail not on the axis (Fig. 84).

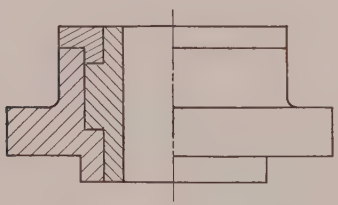


Fig. 85.—A half section.

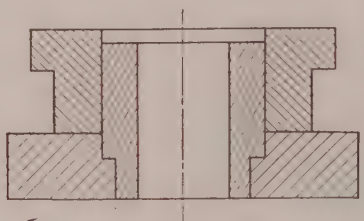


Fig. 86.—Adjacent pieces in section.

45. A half section is a view obtained when the cutting plane extends only half way across, leaving the other side of the piece as a half outside view. It can be used to advantage with a symmetrical piece to show both the exterior and interior on one view (Fig. 85). Hidden lines are generally left out on both sides.

46. To Make a Sectional View.—Think how the object would look if actually sawed in two. Draw all the lines that are in the plane of the section and all visible edges back of the plane, but only such hidden (invisible) edges as are necessary to describe the shape of the object. When two or more pieces are shown together, they are sectioned in different directions (Fig. 86). Any one

piece must have the section lines in the same direction on all parts of its cut surface.

47. Section Lining.—The spacing of section lines should be such as will give the effect of an even tint. For most purposes the distance between lines is about one-sixteenth inch, spaced entirely by eye. Uneven spacing not only will ruin the appear-

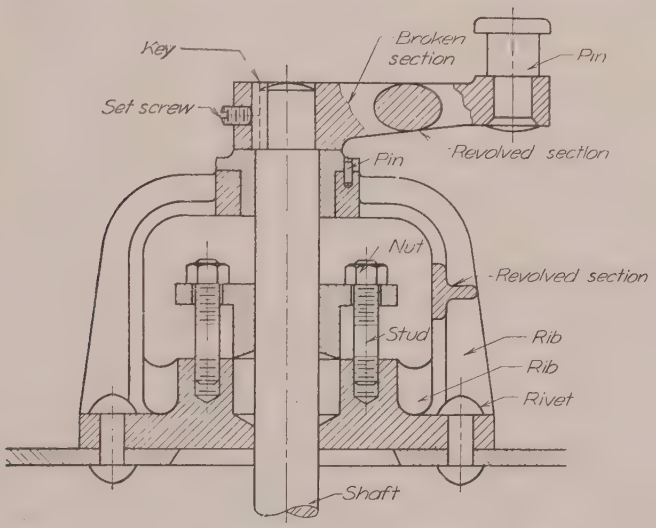


FIG. 87.—Bolts, shafts etc., on sectional views.

ance of a drawing but will make it harder to read. Very small pieces require somewhat closer spacing than large ones.

Sometimes different materials are indicated by varying the kinds of section lining. The symbols used when this is done are shown in Fig. 147 (page 73). Ordinarily it is better to use the regular section lining and specify the material by a note.

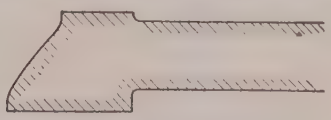


FIG. 88.—Outline section.

48. Special Sections.—When shafts, bolts, nuts, screws, keys, etc., occur in the section, they are not cut through but are left in full as indicated in Fig. 87, where the usual treatment is shown. The purpose of a sectional view is to make interior details clear. Therefore, when parts are solid (have no interior details), they are best represented by full views. Broken sections often permit a single view to show both interior and exterior features. Revolved

sections provide a convenient means of showing the shape of a rib or arm. Note the method of showing the break at the lower end of the shaft.

A timesaving method of indicating a large sectioned area is to use outline sectioning as shown in Fig. 88. This method is often used on design drawings with the section lines drawn freehand.

FIG. 89.—Blacked in section.

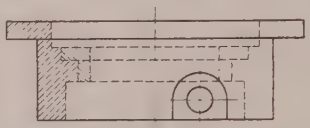


FIG. 90.—Phantom section.

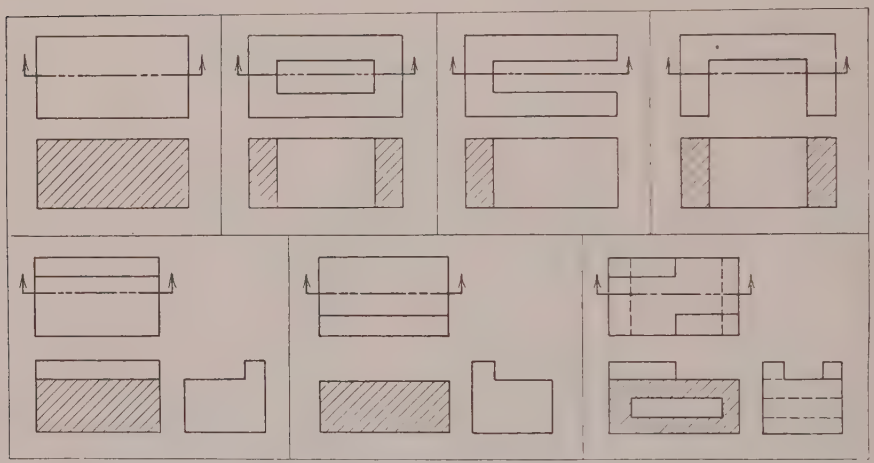


FIG. 91. —Sections for study.

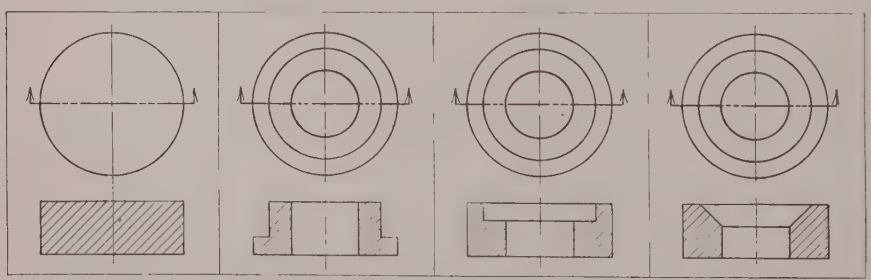


FIG. 92.—Sections for study.

When the sectioned area is very small, as for thin plates, sheets and structural shapes, blacked-in sections may be used as in Fig. 89. Note the white space between the parts.

The hidden, or "phantom," section (Fig. 90) is used when it is necessary to show the interior and exterior on the same view.

49. Sectional View Problems.—Study each piece shown in Figs. 91 and 92 until the reason is clear. Then the objects shown in Figs. 93 and 94 are to be redrawn freehand, changing one of the views of each to a full section, as indicated by the cutting plane. The surfaces which are cut should have light, uniformly spaced section lines, drawn at approximately 45°. Draw the views large enough so that they can be easily read, perhaps about four times the size shown in the book (estimated).

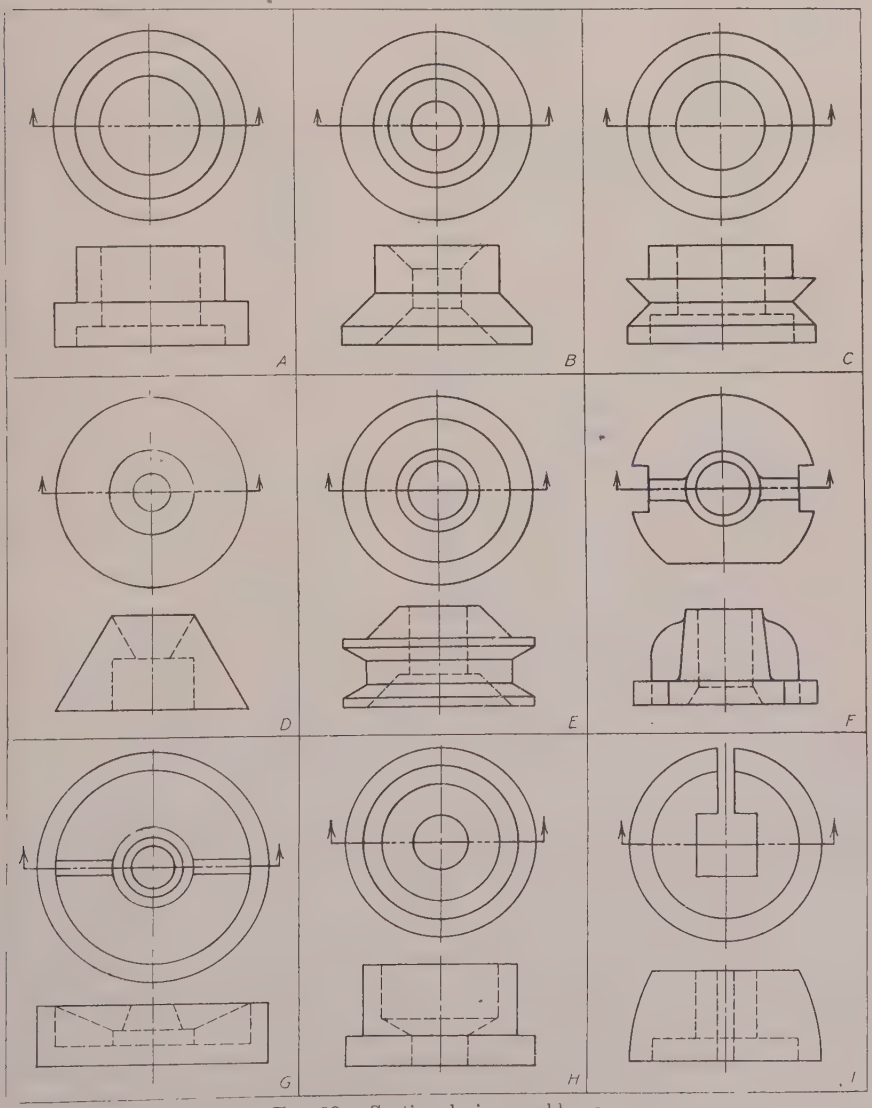


FIG. 93.—Sectional view problems.

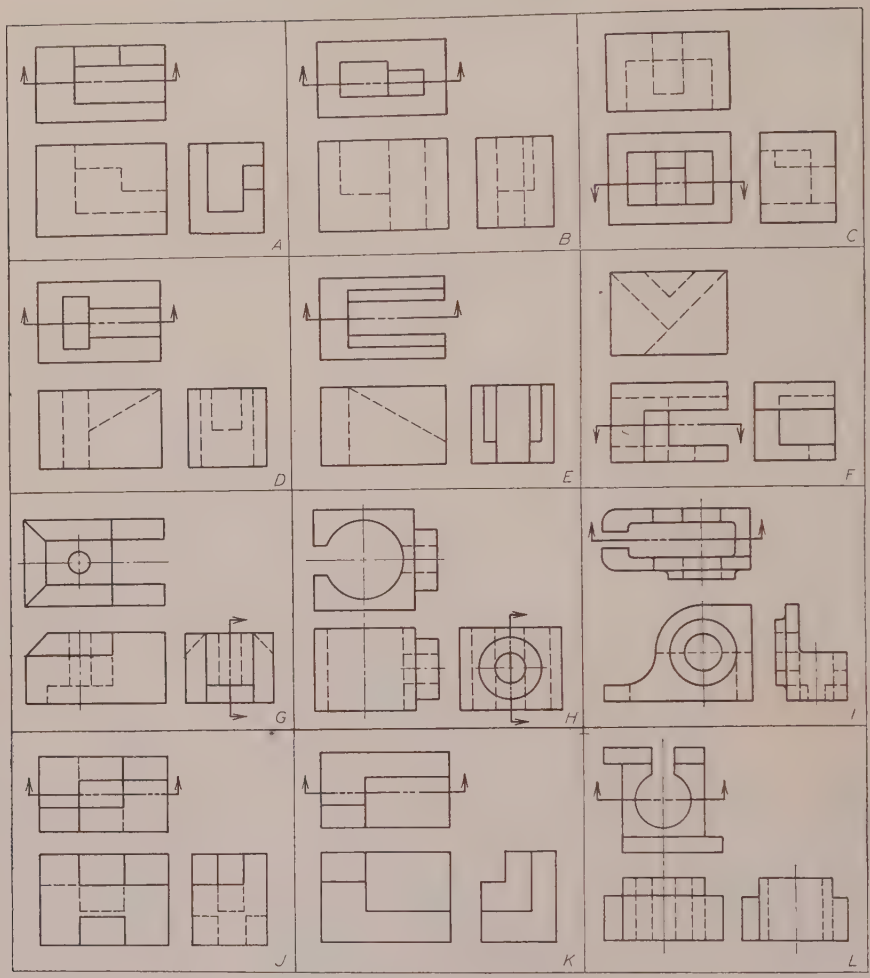


Fig. 94.—Sectional view problems.

CHAPTER VII

AUXILIARY VIEWS AND REVOLUTIONS

50. Auxiliary Views.—The usual views of an object do not show the true shapes of slanting surfaces (Art. 34, Fig. 55). However, it is sometimes necessary or desirable to show the true shape of a slanting surface, especially when it has an irregular outline. This is done by making a view called an "auxiliary view," looking directly at the slanting surface (Figs. 95 and 96). Notice that by drawing the auxiliary view of the washer pictured in Fig. 95 its shape is completely described in Fig. 96 with the auxiliary

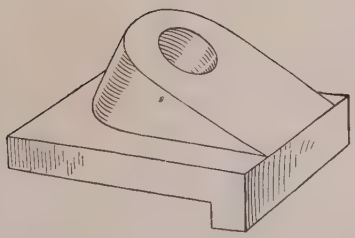


Fig 95.—Angle washer.

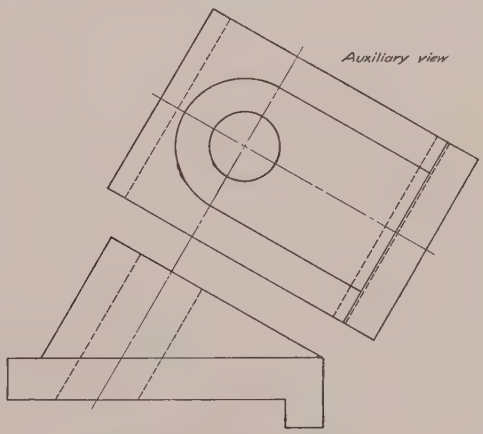


Fig. 96.—An auxiliary view.

view and one of the regular views, making a top or side view unnecessary.

The relation of the auxiliary view to the usual views is illustrated by the simple block in Figs. 97 to 99. The three regular views would be as in Fig. 97, the side view being obtained by looking in the direction of arrow I. The face A does not show in its true shape in this view. But if we locate a plane parallel to face A, as in Fig. 98, and look in the direction of arrow II, perpendicular to face A, we can obtain an auxiliary view which will show the true size and shape of face A. Such an auxiliary view made on an auxiliary plane and revolved into the plane of the paper

is shown in Fig. 99. Other auxiliary views obtained in the same manner are shown in Figs. 100 and 101.

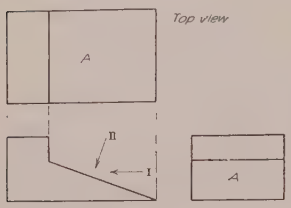


FIG. 97.

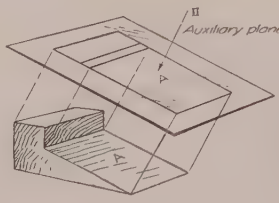


FIG. 98.

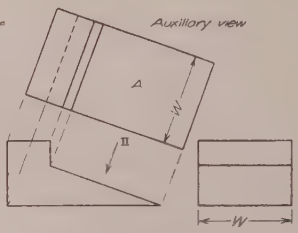


FIG. 99.

51. Kinds of Auxiliary Views.—Auxiliary views may be classified according to the positions of the planes upon which they are obtained.

Auxiliary elevations are auxiliary views made on planes that are perpendicular to the horizontal plane (Fig. 102).

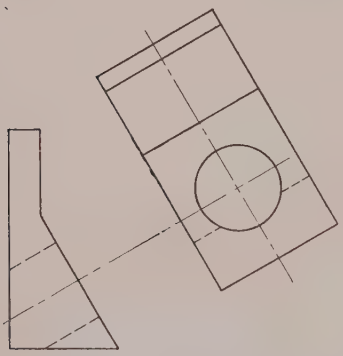


FIG. 100.—An auxiliary view.

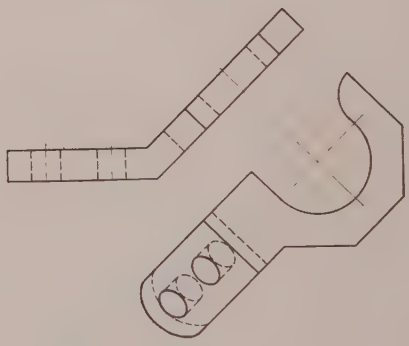
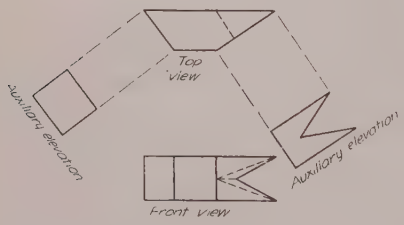


FIG. 101.—An auxiliary view.

Left- or *right-auxiliary views* are auxiliary views made on planes that are perpendicular to the vertical plane (Fig. 103).



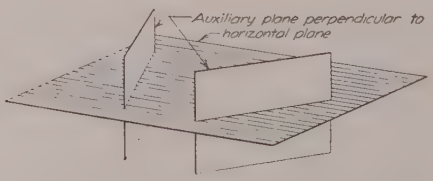


FIG. 102.—Auxiliary elevations.

Front- and *rear-auxiliary views* are auxiliary views made on planes that are perpendicular to the side or profile plane (Fig. 104).

52. Practical Auxiliary Views.—When working drawings for practical use are being made, the object can often be described by partial views, as for the casting shown in Fig. 105, drawn with a partial auxiliary view and a partial top view.

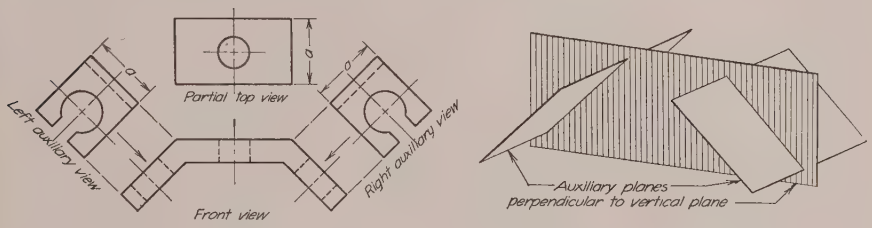


FIG. 103.—Left- and right-auxiliary views.

53. To Draw an Auxiliary View.—It is evident that the width of an auxiliary view projected from a front view is the same as the width of the top or side view (see *W*, Fig. 99).

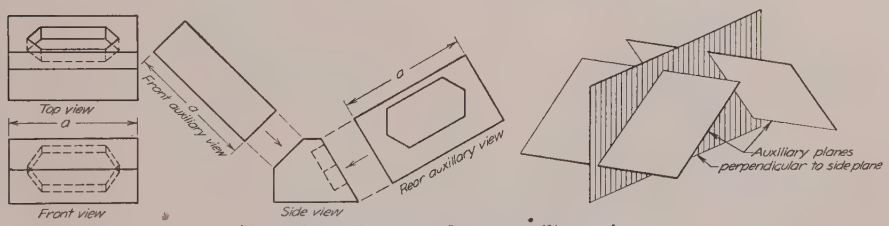


FIG. 104.—Front- and rear-auxiliary views.

Center lines are used for the solution of symmetrical objects. Thus for a symmetrical object such as the hexagonal prism (Fig.

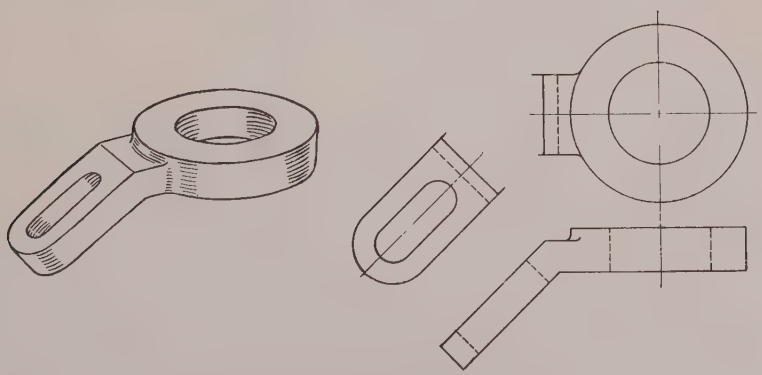


FIG. 105.—Use of partial views.

106), draw a center line for the auxiliary view parallel to the inclined face at any convenient distance from it and a horizontal

center line through the top view. Draw projecting lines perpendicular to the inclined face from each point. On each of these lines locate the auxiliary view of the point projected by measuring the distance of the point from the center line on the top view and marking off this distance from the center line of the auxiliary view.

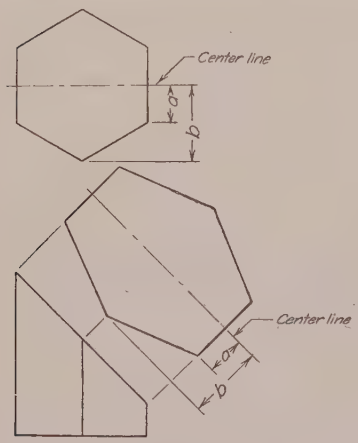


Fig. 106.—Auxiliary view from center line.

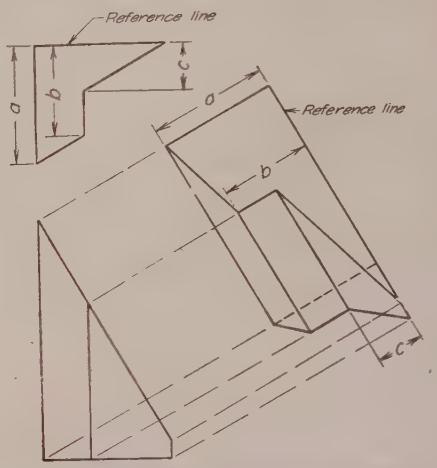


Fig. 107.—Auxiliary view from reference line.

Distances *a* and *b* are toward the front of the object as shown in the top view and therefore are measured toward the front in the auxiliary view. Since the figure is symmetrical, the same distances would be measured on the other side of the center line and

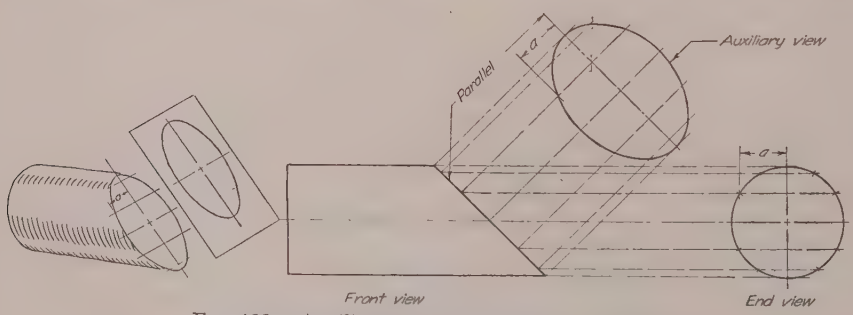


Fig. 108.—Auxiliary view of cut face of cylinder.

the auxiliary view of the inclined face completed by joining the numbered points. In Fig. 106 only the inclined face has been drawn, but the entire object would be projected in the same way.

Reference lines are used for the solution of unsymmetrical objects. Thus for an unsymmetrical object, such as Fig. 107, a

reference line is used, placed for convenience in taking measurements. In this case the reference line is placed at the back of the object so that all measurements are laid off toward the front view.

Auxiliary views of curved outlines are obtained by locating a number of points on the curves. This is illustrated by the auxiliary view of the inclined surface of a cylinder (Fig. 108). In this case the vertical center line of the side view, which shows the end of the cylinder, is the line from which measurements are made and transferred to the auxiliary view. Select a convenient number of points on the front view of the inclined surface and draw perpendiculars from them to the auxiliary center line. Project the same points to the side view, measure the distance from the center

FIG. 109.—Revolutions.

line to each point and lay it off on each side of the center line in the auxiliary view.

54. Revolutions.—It is generally possible to place an object in a simple position so that most of its lines show in their true length or can be easily located in the usual views. Ordinarily, drawings are made in this way. However, it is, of course, possible to represent an object tipped about one of its edges or resting on one of its corners or, as in Fig. 109, revolved about its axis.

55. To Draw the Views (Horizontal Axis of Revolution).—First draw the views of the object in its natural position, then revolve to a new position about one or more imaginary axes taken perpendicular to the planes of projection.

At *A* in Fig. 110 we have two views of an object in a natural position. Suppose a hole is drilled through from the front and a shaft inserted as shown. The object might be revolved about the shaft or axis into a new position as at *B*. It will be observed that the front view of *B* is the same as the front view of *A*, except that

its position has been changed. The top view of B is obtained by projecting up from the new front view and across from the top view of A.

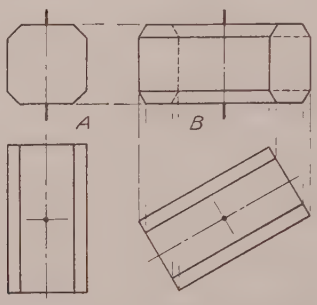


FIG. 110.—Revolution, horizontal axis.

56. The Rule of Revolution.—This rule may be stated in two parts:

1. *The view perpendicular to the axis of revolution is unchanged except in position.*

2. *Distances parallel to the axis of revolution are unchanged.*

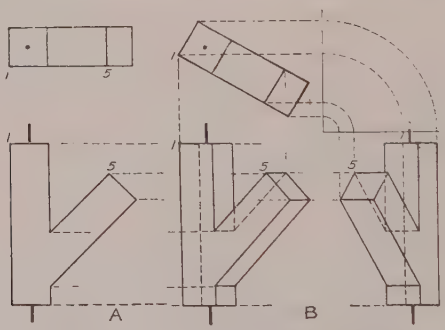


FIG. 111.—Revolution, vertical axis.

57. Vertical Axis of Revolution.—In Fig. 111 the method of drawing an object when revolved about a vertical axis is shown. Given the two views, as at A, it is required to draw three views after the piece has been revolved through 30° about a vertical axis. First draw the top view in its new position B. Since the axis is vertical, the height has not been changed; so a horizontal projecting line may be drawn from point 1 of the front view in A and a vertical projecting line from the top view in B. The intersection of the two lines just drawn will locate the position of point 1 in the new front view. Proceed in the same way for each

point, and join the points to complete the view. The side view is obtained from the front and top views in the usual manner.

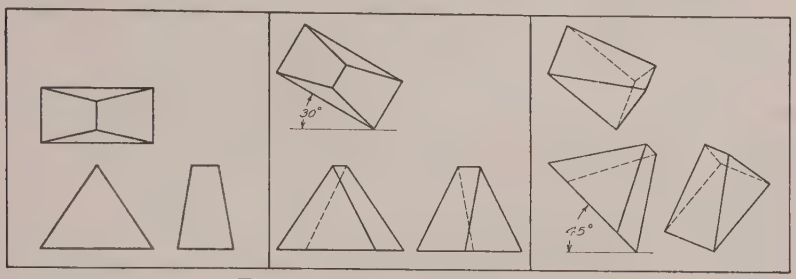


Fig. 112.—Successive revolutions.

58. Successive Revolutions.—After an object has been revolved about an axis perpendicular to a plane, it may be revolved about an axis perpendicular to another plane. This is double, or successive, revolution and is illustrated in Fig. 112, where the piece has been revolved about a vertical axis through 30° and from this position about an axis perpendicular to the vertical plane through 45°.

59. An object may be revolved to the right or to the left about an axis perpendicular to either the horizontal or the vertical plane; or it may be revolved forward or backward about an axis perpendicular to the side plane, in which case the side view would be the unchanged view, and the widths of the front and top views would be the unchanged distances.

CHAPTER VIII

PRINCIPLES OF SIZE DESCRIPTION

60. Size. –We have learned that the two things to be told about an object are its shape and its size. In the previous chapter we studied the methods of representing the shape. When information regarding the *size* is added to the shape description, the two together give the complete working drawing of the object.

FIG. 113.—Size accuracy. (*Monarch Machine Tool Company.*)

"Measuring roundness, smoothness, and straightness of work. Monarch engineers do not guess as to the roundness or straightness of a piece of work . . . they do not take the smoothness of a finished surface for granted . . . they do not wonder whether gear tooth marks or tool marks show. They use the finest testing instruments to insure absolute accuracy. In the photograph, the operator is using the Zeiss optometer which records errors as small as .0000012", to measure the roundness, smoothness and straightness of work turned out on a Model "C" Tool Room Lathe."

Size description is, then, an essential and important part of a working drawing. For some purposes the specification of nominal and ordinary sizes is sufficient while for others an extreme degree

of accuracy may be required as illustrated in Fig. 113 from The Monarch Machine Tool Company, Sidney, Ohio.

While working drawings are always made to scale, it would require too much time to take off distances by applying a scale to the drawing. Furthermore, the chances of making a mistake

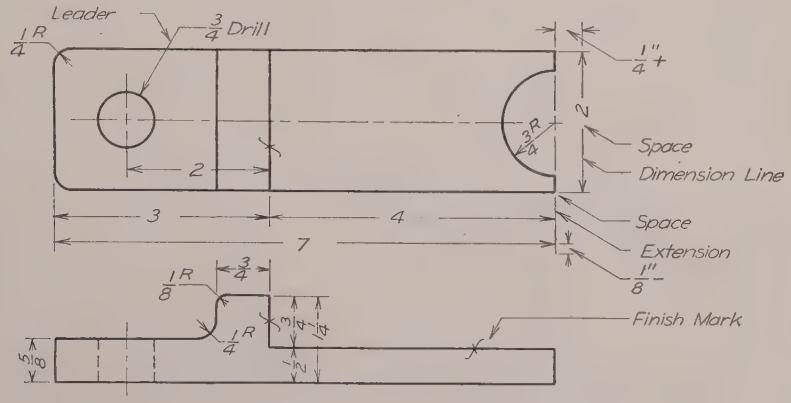


FIG. 114.—Dimensioning.

would be numerous, especially with small distances or for drawings made to small scale.

For convenience in using, insuring accuracy and saving time, the size description is given in the form of dimensions and notes arranged on the drawing in a definite manner.

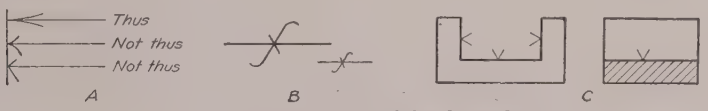


FIG. 115.—Arrows and finish marks.

61. Lines, Figures, Arrows, Etc.—Certain conventional lines and symbols are used on drawings. To make a successful drawing, the draftsman must be familiar with these symbols, must know the principles of dimensioning and must be acquainted with the shop processes which will be used in building or making the object represented.

The dimension line is made a light full line in contrast with the heavier shape outline (see Art. 77, Alphabet of Lines). The line is terminated by long pointed arrowheads (Fig. 114). Great care must be taken to have all arrowheads the same size and correctly shaped (Fig. 115 at *A*).

62. "Finished" or machined surfaces are indicated by the symbol (*f*) shown enlarged and natural size at *B* in Fig. 115. A new symbol is being considered for American Standard which consists of a V touching the line which represents the finished surface as shown at *C* in Fig. 115.

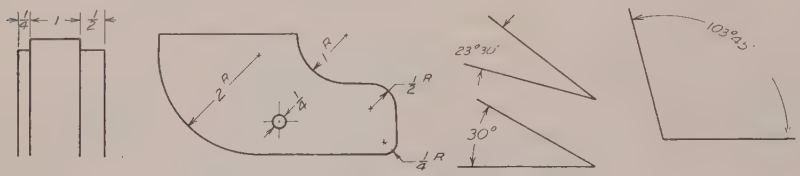


Fig. 116.—Radii, angles, etc.

A space is left in the dimension line for a figure to tell the actual distance on the full-size piece. When the dimension is placed outside the outline of the view, *extension* or *witness* lines are drawn from the view to show the points or surfaces measured on the object. Extension lines are fine lines drawn from the outline and extending past the arrowhead. Since extension lines are not part of the shape, they should not touch the outline (see Fig. 114).

63. Figures must be carefully made and of a size easily readable but not so large as to overbalance the drawing. In general, make them about $\frac{1}{8}''$ high. To avoid crowding, dimension lines should be $\frac{1}{4}''$ or more from the lines of the drawing and from each other. A fraction is *always* made with a horizontal division line. Figures for fractions are made about two-thirds the height of whole numbers (see Fig. 29).

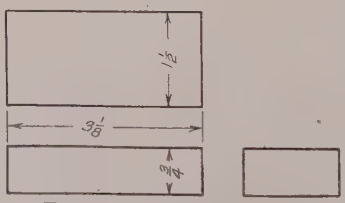


Fig. 117.—The first shape.

64. Placing Dimensions.—In placing dimensions the important thought is to have in mind the man who has to read the drawing and make the piece from it. It is necessary to think of the actual piece in space. Since the shape is already defined, select the view which tells most about the piece and give two dimensions of each part. One of the other views must be used to tell the third

distance. In general, it is better to place the dimensions between the views so as to be near both views. Horizontal dimensions must always read from the bottom of the sheet and vertical dimensions from the right side of the sheet, no matter what part of the sheet they are on.

Inches are indicated by $''$ and feet by $'$, and a dash is always placed between feet and inches, thus $5'\text{-}7\frac{1}{2}''$, or $0'\text{-}9\frac{1}{4}''$. When the drawing is dimensioned entirely in inches, the inch marks may be omitted (Fig. 114). When the space is too small to admit arrowheads and figures, one of the methods of Fig. 116 is used.

Angles are dimensioned by drawing an arc, with the dimension horizontal except for large arcs (Fig. 116).

When there are few lines within the outline, dimensions may be placed inside, making it unnecessary to draw extension lines.

The letter *D* should be placed after a dimension indicating a diameter unless evident from the drawing. The letter *R* should always be placed after the dimension for a radius (Fig. 116). Dimension lines should never cross extension lines. Larger dimensions should be placed outside smaller dimensions.

65. Theory of Dimensioning.—The theory of dimensioning is based upon the idea of considering any object as made up of a number of simple shapes. When the size of each simple piece is defined and the relative positions given, the size description is complete. **Size dimensions** are used to define the simple pieces and **location dimensions** to give relative positions. When a number of pieces are assembled, each piece is first considered separately and then in relation to the other pieces. In this way the size description of a complete machine, of a piece of furniture or of a building is no more difficult than the dimensioning of a single piece.

66. Size Dimensions.—The first shape is a flat piece, requiring the length, breadth and thickness (Fig. 117). Such an elementary shape may appear in a great many ways, a few of which are shown in Figs. 118 and 119.

Flat pieces of irregular shape are dimensioned in a similar way (Figs. 120 and 121).

RULE.—*For any flat piece give the thickness in one of the edge views and all other dimensions on the outline view.*

The second shape is the cylinder, requiring two dimensions, namely, the diameter and the length (Fig. 122). A washer or

other hollow cylinder may be thought of as two cylinders (Fig. 123), requiring two diameters and one length.

RULE.—*For cylindrical pieces give the diameter and length on the same view.*

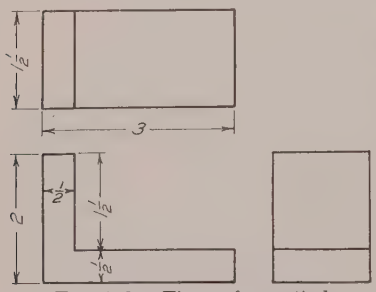


FIG. 118.—First rule applied.

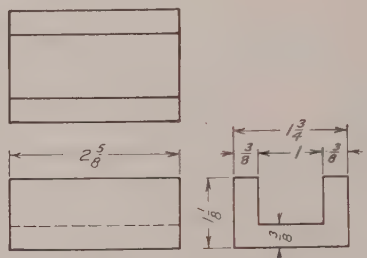


FIG. 119.—First rule applied.

When a note is used to give the size of a hole (negative cylinder), it is generally placed on the outline view, especially when the method of forming the hole is specified (Fig. 124). When parts of cylinders occur, such as fillets, rounds, rounded corners, etc., they are dimensioned in the views where the curves show (Fig. 124).

Other shapes include the cone, pyramid and sphere. The cone, or frustum, the square pyramid or the sphere may be dimensioned in one view. The dimensions for rectangular or other pyramids and parts of pyramids require the use of two views.

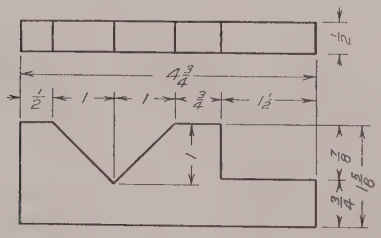


FIG. 120.—An irregular flat shape.

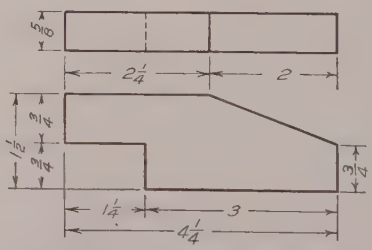


FIG. 121.—An irregular flat shape.

67. Location dimensions are used to specify the relative positions of the simple parts which make up most constructions and to locate various holes, surfaces and other features. The relative importance of the various surfaces and axes must be studied together with the question of accuracy. A knowledge of engineering practice in manufacture, assembling and use is sometimes essential to a complete understanding of the necessary dimensions. Finished surfaces and center lines or axes are used to

define positions with location dimensions. Two general rules will serve as a basis for the application of location dimensions.

RULE.—*Prism forms are located by axes and surfaces* (*Fig.* 125). *Three dimensions are required.*

RULE.—*Cylinder forms are located by the axis and the base* (*Fig.* 126). *Three dimensions are required.*

Combinations of prisms and cylinders are shown in Figs. 127 and 128. The dimensions *A*, *B* and *C* (Fig. 128) are location dimensions.

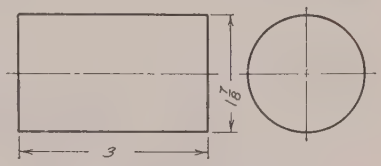


FIG. 122.—The second shape.

68. General Rules.—In the application of dimensioning there are certain practices which have come to represent good form to such an extent as to have the force of rules.

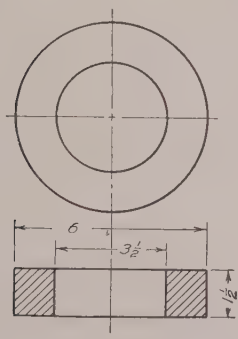


FIG. 123.—Second rule applied.

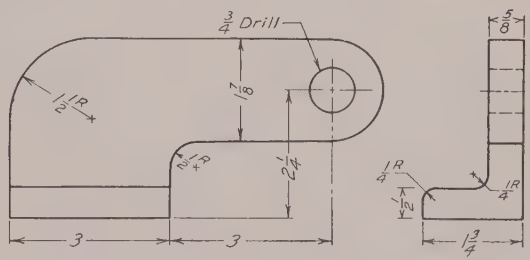


FIG. 124.—Fillets and rounds.

1. Regardless of location on the sheet, dimensions must read in line with the dimension line and from either the lower or right-hand side of the sheet.

2. On machine drawings detail dimensions up to 72″ should be given in inches. Above this, feet and inches are generally used, except for gear drawings, bore of cylinders, length of wheel bases, etc.

3. When all the dimensions are in inches, the symbol (″) is preferably omitted.

4. On architectural and structural drawings, dimensions of 12″ and over are given in feet and inches.

5. Sheet-metal drawings are usually dimensioned entirely in inches.

6. Furniture and cabinet drawings are usually dimensioned in inches.

7. Feet and inches are designated thus, 7′-3″ or 7 ft.-3 in. Where the dimension is in even feet, it is indicated thus, 7′-0″.

8. The same dimension is not repeated on different views unless there is a special reason for it.

9. When it is necessary to place a dimension within a sectioned area, do not run the section lines across the number (Fig. 129).

10. Dimensions should be given from or about center lines. Finished surfaces are always located from other finished surfaces or from center lines.

11. Never use a center line or a line of the drawing as a dimension line.

12. Never have a dimension line a continuation of a line of the drawing.

13. Never place a dimension so that it is crossed by a line.

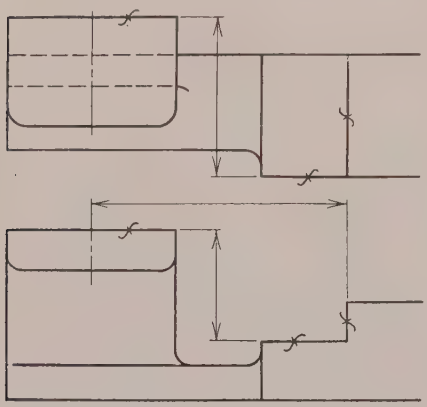


FIG. 125.—Location dimensions for prisms.

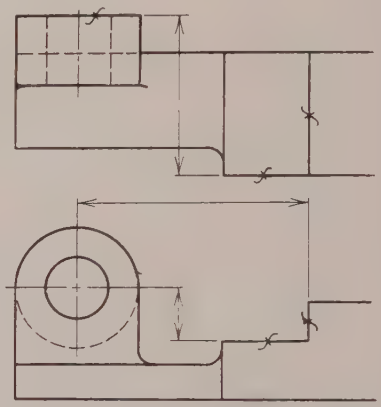


FIG. 126.—Location dimensions for prisms.

14. Always give the diameter of a circle, not the radius. The abbreviation *D* is used after the dimension, except when the fact that it is a diameter is obvious.

15. Always give the radius of an arc. The abbreviation *R* is used after the dimension.

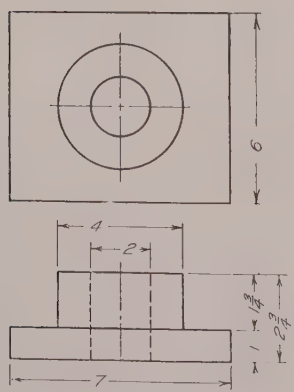


FIG. 127.—First and second shapes.

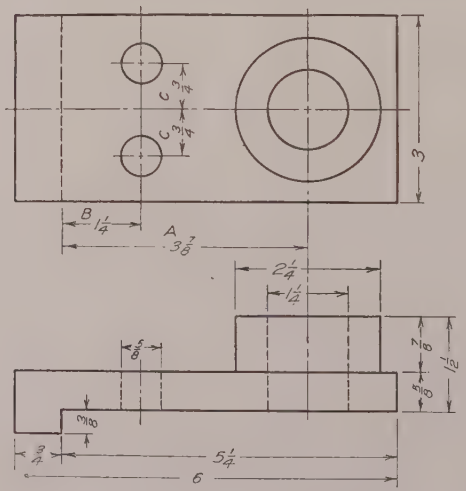


FIG. 128.—First and second shapes.

69. Use of Decimals.—Dimensions are given in feet, inches and fractions of an inch. In ordinary work binary fractions such

as $\frac{1}{2}''$, $\frac{1}{4}''$, $\frac{1}{8}''$, $\frac{1}{16}''$, $\frac{1}{32}''$, $\frac{1}{64}''$ are used. For parts that must fit very accurately the dimensions are given in decimals instead of the usual fractions, and the workman is required to work within a certain fixed limit of accuracy. The number of thousandths or ten-thousandths of an inch which will be allowed as variance from the absolute measurement is called the "tolerance." The limits between which the measurement must come are given in Fig. 130, which shows that the diameter of the hole must not be over 0.8130″ or under 0.8125″.

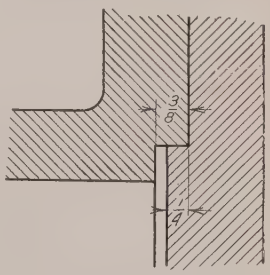


FIG. 129.—Rule 9.

70. Dimensioning Assembled Parts.—The drawing of a separate part is called a "detail drawing." When the different parts of a machine or structure are shown together in their relative positions, the drawing is called an "assembly drawing." The rules and methods given for dimensioning apply to all cases where a complete description of size is required.

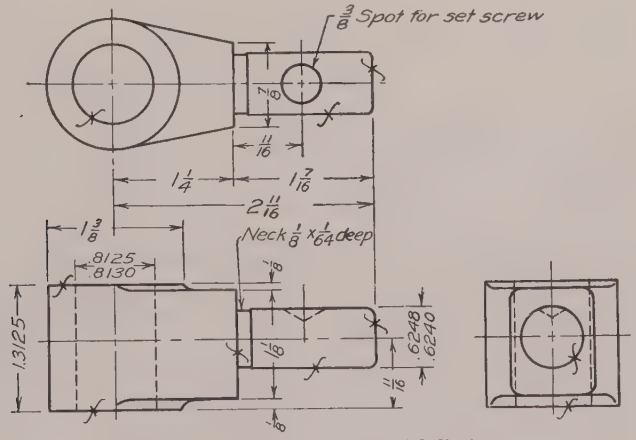


FIG. 130.—Dimensioning with limits.

Drawings of complete machines, pieces of furniture, etc., are made for different uses and have to be dimensioned to serve the purpose required of them. If the drawing is merely to show the arrangement of parts, all dimensions are left off. When it is desired to tell the space required, give "over-all" dimensions. Where it is necessary to locate parts in relation to each other without giving all the detail dimensions, it is usual to give center distances and sizes of parts which might affect putting together

the machine or construction. Assembly drawings may be completely dimensioned either with or without extra part views (see Fig. 188). Such drawings serve the purpose of both detail and assembly drawings.

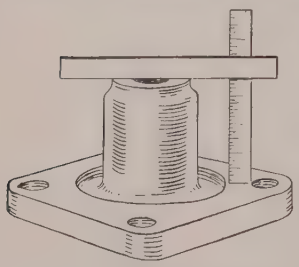


Fig. 131.—Taking a measurement.

For furniture and cabinet work the major dimensions only are sometimes given, such as length, breadth, height and sizes of stock, leaving the details of joints to the cabinetmaker. This is common practice where machinery is used and where many details of construction are standardized.

71. Sketching and Measuring.—Sketching as a means of shape description and study has been considered in Chap. V. When sketches that are to be used in making drawings are made from machine or furniture parts, it is necessary to define the size, the

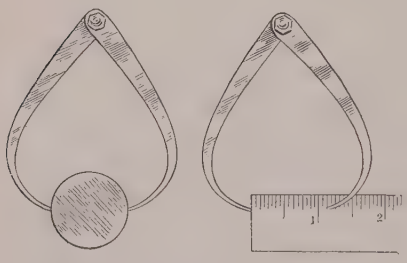


Fig. 132.—Outside calipers.

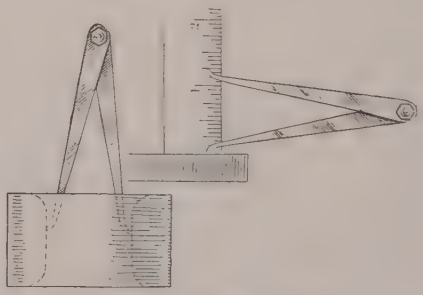


Fig. 133.—Inside calipers.

material, the kinds of surfaces, either "finished" or "rough," the limits of accuracy and all information that might have any possible future value.

72. After sketching the views of a piece, add all necessary dimension lines in exactly the same way as for a drawing. The piece should now be examined, the kind of material noted, together with the kinds of finish and the location of all finished surfaces. When everything else is done, it is time to measure the piece and fill in the figures, telling the size. For this purpose various measuring tools will be required. A two-foot rule, a steel scale and a pair of calipers will be found sufficient for most measurements. Other machinists' tools are often necessary or convenient and the pupil should know something about the tools that are available and how to use them.

73. The flat scale or the steel scale and straightedge can be used in many ways, as suggested in Fig. 131, and the distances read directly.

Whenever possible, always take measurements from finished surfaces. Outside and inside calipers with their use illustrated are shown in Figs. 132 and 133. The distance between the contact points is read by applying the calipers to a scale.

When the calipers cannot be removed from a thickness, the plain calipers may be used by inserting an extra piece or "filler" (Fig. 134); or the "transfer" calipers (Fig. 135) may be used. The distance x must be subtracted from the total distance to obtain the desired thickness t when a filler is used. The transfer calipers are provided with a false leg which is set so that the

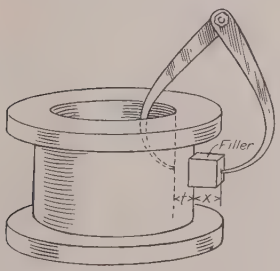


FIG. 134.—Using a filler.

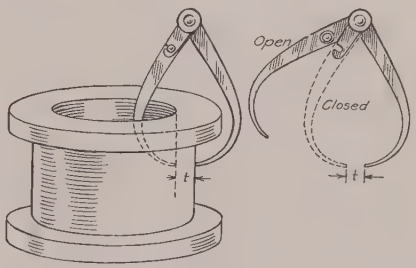


FIG. 135.—Using transfer calipers.

calipers may be opened and then brought back to the same position after removing from the casting.

All measurements of wood construction can generally be obtained with sufficient accuracy by using the two-foot rule.

For very accurate measurements vernier calipers and micrometer calipers (Figs. 136 and 137) are used. Other tools which are useful, if at hand, are the steel square, try square, combination square, surface gage, depth gage, radius gages, protractor, etc.

When a pictorial sketch is dimensioned, the only additional consideration is to use care to see that all extension lines are either in or perpendicular to the plane on which the distance is being given (Fig. 138).

74. Notes and Specifications.—Information which cannot be represented graphically must be given in the form of lettered notes and symbols. Generally understood trade information is often given in this way. Such notes include the following items: number required, material, kind of finish, kind of fit, method of machining,

kinds of screw threads, kinds of bolts and nuts, sizes of wire, thickness of sheet metal, etc.

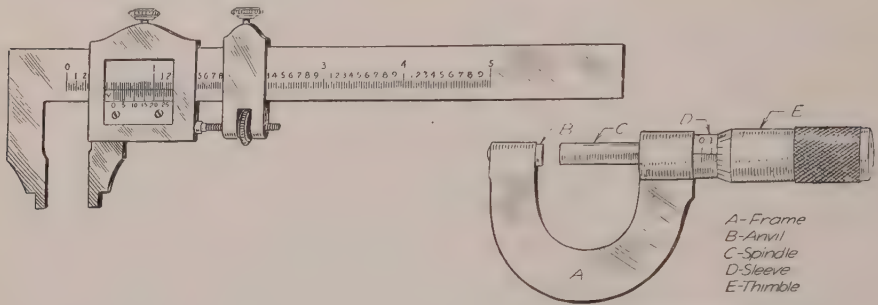


FIG. 136.—Vernier calipers.

FIG. 137.—Micrometer calipers.

The materials in most general use are wood, cast iron, wrought iron, steel and brass. All parts which go together must be of the proper size so that they will fit. Some pieces are left in the rough, and others must have a smooth "finish." The wood used for making a piece of furniture is first shaped with woodworking tools. Cast iron and brass are given the required form by molding, casting and machining. First, a wood "pattern" of the shape and size required is made. This pattern is placed in sand to make an impression or mold, into which the melted metal is poured. Wrought iron and steel are made into shapes by rolling or forging in the rolling mill or blacksmith shop. Some kinds of steel may be cast as described for cast iron.

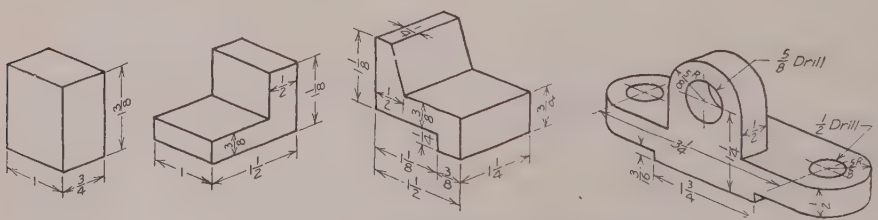


FIG. 138.—Dimensioning a pictorial sketch.

There are many interesting ways of forming metals for special purposes and many special alloys that cannot be described in a drawing book but the pupil will learn much by observing the shapes of parts of machinery and the materials of which they are made.

After a part is cast or forged, it must be "machined" on all surfaces which are to fit other surfaces. Round surfaces are generally formed on a lathe. Flat surfaces are finished or smoothed

on a planer, milling machine or shaper. For making holes, drill presses, boring mills or lathes are used.

Extra metal is allowed for surfaces that are to be finished. To specify such surfaces a small $\int$ is placed on the lines which represent the surfaces. If the entire piece is to be finished, a note, such as "*fin. all over*," may be used, and all other marks omitted.

Specifications as to methods of machining, finish and other treatment are given in the form of notes, as spot-face, grind, polish, knurl, core, drill, ream, countersink, harden, caseharden, blue and temper.

It is often necessary to add notes in regard to assembling, order of doing work or other special directions.

75. Checking a Drawing.—After a drawing has been completed, it must be very carefully examined before it is used. This is called "checking the drawing." It is very important work and should be done by someone who has not worked on the drawing.

Thorough checking requires a definite order of procedure, and consideration of the following items:

1. See if the views completely describe the shape of each piece.
2. See if there are any unnecessary views.
3. See that the scale is sufficiently large to show all detail clearly.
4. See that all views are to scale and that correct dimensions are given.
5. See that sufficient dimensions are given to define the size of all parts completely.
6. See that the kind of material and the number required of each part is specified.
7. See that the kind of finish is specified, that all finished surfaces are marked and that finish is not called for where not needed.
8. See that all necessary explanatory notes are given, and that they are properly placed.

An incorrect drawing with some of the mistakes noted on it is shown in Fig. 139, and the same drawing when corrected in Fig. 140. Go over the incorrect one carefully, checking the mistakes in both drawing and dimensioning, then compare with the corrected drawing below it, noticing how the mistakes have been corrected and the dimensions rearranged. Observe how much easier the drawing is to read when drawn correctly with lines of proper weight and dimensions put on according to the rules of dimensioning.

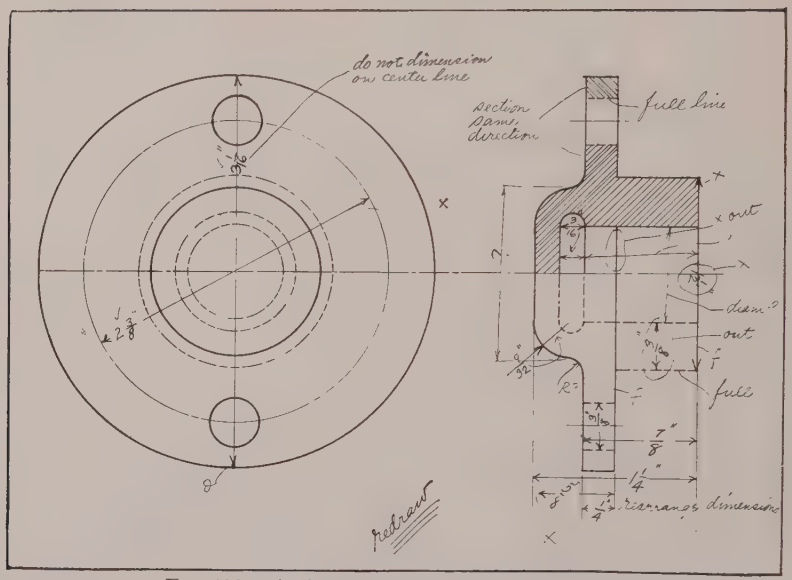


FIG. 139.—An incorrect drawing to be checked.

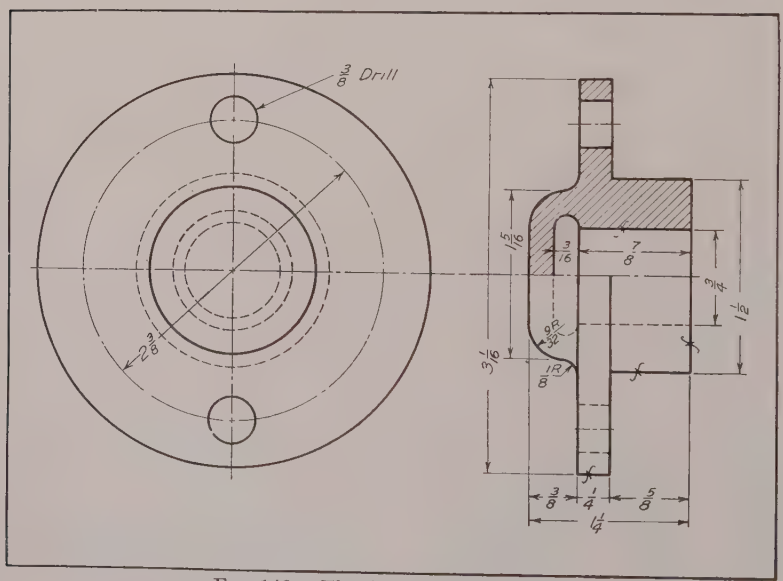


FIG. 140.—The drawing as corrected.

CHAPTER IX

TECHNIC OF THE FINISHED DRAWING

76. It has been impressed upon us that in the language of drawing an object is described by telling its shape and its size. All drawings whether for machinery, structural work, buildings or ships are made on the same principles.

Sometimes an unfavorable comparison is made between a *student's* drawing and a *real* drawing. The finished appearance of a real drawing as made by a draftsman or engineer is due to a thorough knowledge of the technic of commercial drafting.

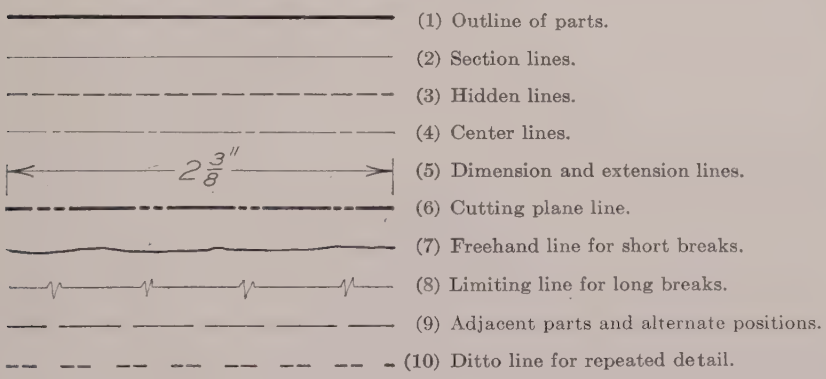

2 3/8"
(1) Outline of parts.
(2) Section lines.
(3) Hidden lines.
(4) Center lines.
(5) Dimension and extension lines.
(6) Cutting plane line.
(7) Freehand line for short breaks.
(8) Limiting line for long breaks.
(9) Adjacent parts and alternate positions.
(10) Ditto line for repeated detail.

FIG. 141.—The alphabet of lines.

The correct order of going about the work and some of the conventional representations in common use are described in this chapter. The pupil must become thoroughly familiar with this practice if his drawings are to have the style and good form that are so desirable and necessary.

77. Alphabet of Lines.—The kinds of lines given in the American Standards for use in making drawings are shown in Fig. 141. Each line is used for a definite purpose and must not be used for anything else. Detail drawings should have fairly heavy outlines with light center lines and dimension lines so that the drawing will have contrast and be easy to read. If all the lines are the same weight, the drawing will have a *flat* appearance which makes it hard to read.

The lines shown are for inked drawing and tracings. On pencil drawings two weights of lines may be used, medium and light.

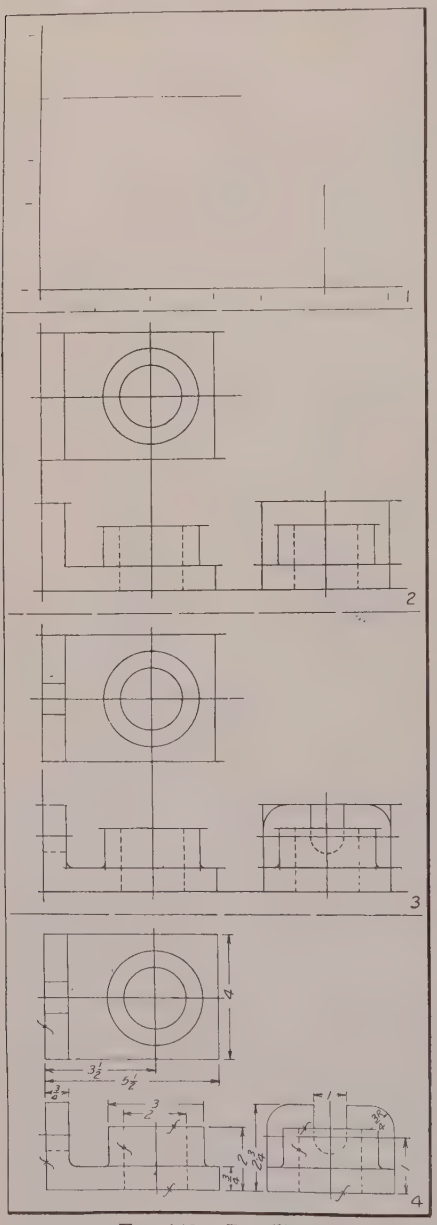


FIG. 142.—Penciling.

78. Order of Penciling.—After learning about shape and size description, the most important thing for the young draftsman to get is good form, a systematic method of working. The order of making the different parts of the drawing is the first item. A drawing is started by drawing the center and base lines, as at (1) in Fig. 142. These form the skeleton for the views. Then block in the views as at (2), draw the arcs and complete the views as at (3). The views should be carried along together. Do not attempt to finish one view before making another. Finally, add the dimension lines and dimensions as at (4). Learn the following order of penciling and follow it as nearly as possible in every drawing.

1. Lay off the sheet to proper size, and block in the title space or record strip.
2. Plan the arrangement of views.
3. Determine the scale to use.
4. Draw the primary center and base lines.
5. Lay off the principal measurements.
6. Block in the views by drawing the preliminary and final "blocking-in" lines.
7. Lay off the detail measurements.
8. Draw the center lines for details. See that two intersecting center lines are drawn to locate all circles, and that there are center lines for the axes of all cylinders.

9. Draw all complete circles and the preliminary and final lines for details.
10. Draw part circles, fillets and rounded corners.
11. Draw such lines as could not previously be drawn.
12. Draw all extension and dimension lines.
13. Put on dimensions and notes.
14. Crosshatch all sectioned surfaces.
15. Letter the title.
16. Check the drawing carefully.

79. Inking and Tracing.—Working drawings are usually finished for use by putting a piece of transparent tracing cloth or tracing paper over the pencil drawing and tracing it. A

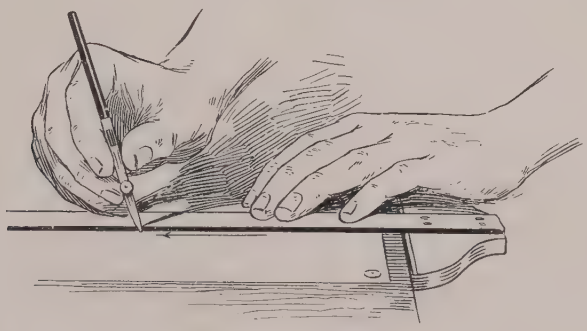


FIG. 143.—Correct position for pen.

great many drawings are traced in pencil on tracing paper or pencil cloth and blue prints made from these tracings. More permanent tracings are made in ink on tracing cloth. Better blue prints can be made from inked tracings on either cloth or paper than from penciled tracings. The method of procedure in inking is the same whether a tracing is made or whether the original drawing is finished by going over the penciled lines with drawing ink.

All straight lines are inked with the ruling pen. Hold the pen point downward and fill by touching the quill on the ink-bottle cork to the inside of the pen blades. The nibs of the pen are set to the desired width of line by turning the adjusting screw, using the thumb and second finger of the pen hand. Then hold the pen against the T-square or triangle in the position of Fig. 143.

Note the following:

Do not hold the pen over the drawing while filling.
Keep the blades parallel to the direction of the line.

Do not press too hard against the T-square.

Do not screw the nibs of the pen too tight.

Have a pen wiper at hand.

Keep the pen clean by frequent wiping. Always wipe it carefully after using.

Never dip the pen into the ink bottle or allow ink to get on the outside of the blades.

Do not put too much ink in the pen (not over one-fourth inch).

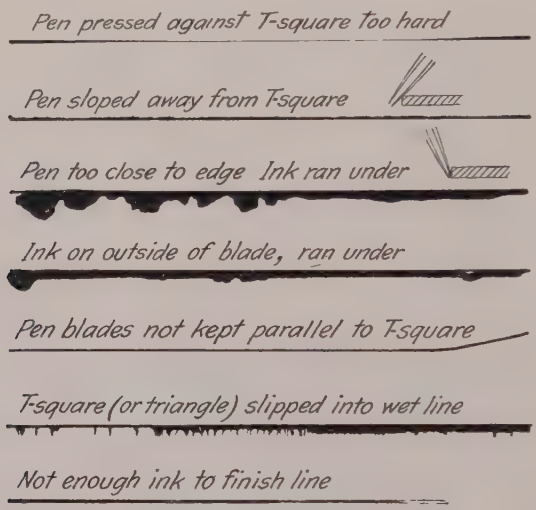

Pen pressed against T-square too hard
Pen sloped away from T-square
Pen too close to edge Ink ran under
Ink on outside of blade, ran under
Pen blades not kept parallel to T-square
T-square (or triangle) slipped into wet line
Not enough ink to finish line

FIG. 144.—Faulty lines.

Faulty lines occur from different causes. The pen may need dressing or sharpening. The beginner should not attempt to do this but should ask the teacher to do it for him. Figure 144 shows some of the common faults and suggests the remedy.

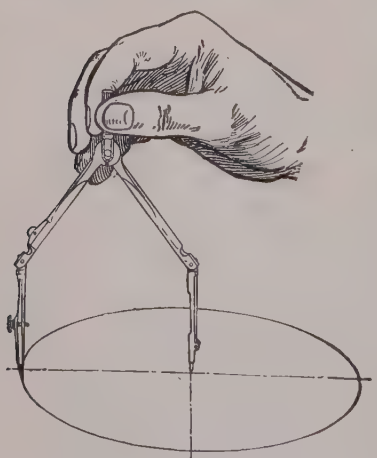


FIG. 145.—Inking a circle.

The irregular curve (Fig. 17) is used for guiding the pen when inking curves other than circle arcs. It is used by matching a portion of the curved line and drawing a piece of the line, then moving the curve to a new position. The new position must always match a part of the line already inked.

For inking circles the compasses and bow pen are used. Remove the pencil leg from the compasses and insert the pen leg, adjusting

the needle point until it is very slightly longer than the pen. The joints of the compasses should be adjusted so that the legs are perpendicular to the paper. Always draw a circle in one stroke, inclining the compasses in the direction of the line and rolling the handle between the thumb and finger (Fig. 145). Small circles are drawn with the bow compasses as illustrated and described on page 10.

80. To Make a Tracing.—If tracing cloth is used, first tear off the selvage and fasten the cloth down smoothly over the pencil drawing. Most draftsmen place the dull side up. Dust the surface with chalk and rub over with a cloth to remove all traces of grease, so that the ink will "take." Be sure to remove all dust before starting to ink. In inking on paper, chalking is not necessary.

As tracing cloth is very sensitive to atmospheric changes and will stretch if left overnight, no view should be started which cannot be finished on the same day. When work is again started, the cloth should be restretched.

81. Order of Inking.—The general order of inking or tracing is shown in stages in Fig. 146. The arcs are inked first as at (1) and should center over the pencil lines. Horizontal lines have been inked at (2) and the drawing completed at (3). Then add the dimension lines, arrowheads, finish marks, etc., and fill in the dimensions. Good inking is the result of two things: careful practice and a definite order of working. Smooth joints and tangents, sharp corners and neat fillets not only improve the appearance of a drawing but make it easier to read.

1. Ink main center lines.
2. Ink small circles and arcs.
3. Ink large circles and arcs.
4. Ink dotted circles and arcs.
5. Ink irregular curves.
6. Ink horizontal full lines.
7. Ink vertical full lines.
8. Ink inclined full lines.
9. Ink dotted lines.
10. Ink center lines.
11. Ink extension and dimension lines.
12. Ink arrowheads and figures.
13. Ink section lines.
14. Letter notes and titles.
15. Ink border lines.
16. Check drawing carefully.

82. Erasing.—The ideal way, of course, is to complete a drawing or tracing without having to do any erasing. Sometimes, however, it is necessary to make an erasure because of a change or a mistake. Ink lines may be removed by rubbing rather hard with a pencil eraser, which does not abrade the surface of the paper or cloth as does an ink eraser. *Do not use a knife or*

scratcher. An erasing shield is very convenient. One can be made by cutting a slot in a card or piece of sheet celluloid. Pencil lines are removed with artgum or a pencil eraser. Electric erasing machines are now used in large drafting rooms. They consist of a small motor with provision for holding a cylindrical eraser on the end of a revolving shaft.

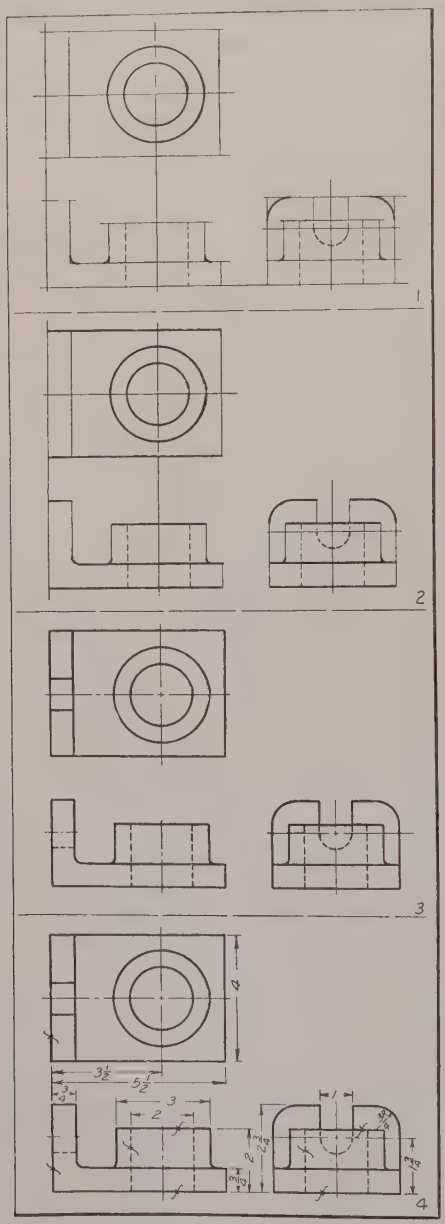


FIG. 146.—Tracing or inking.

83. Conventional Symbols.—In drawing there are conventional methods of representing parts and materials, designed for saving time and making reading easier, that might be called idioms and abbreviations of the graphic language. The commonest are the symbols for indicating screw threads, explained in the next chapter. Other conventions are used for representing electrical apparatus, piping, wiring, etc.

In indicating the material of which a piece is to be made, the best rule is to letter the name of the material as a note; but when adjacent pieces of different materials are shown in section, they can sometimes be shown to better advantage by using symbolic section lining. The symbols for cut surfaces, as given by a committee of the American Standards Association, are shown in Fig. 147. Notes are generally used to tell the materials with outside views but certain distinctive materials are sometimes indicated by the symbols shown in the lower row of Fig. 147. Architectural draw-

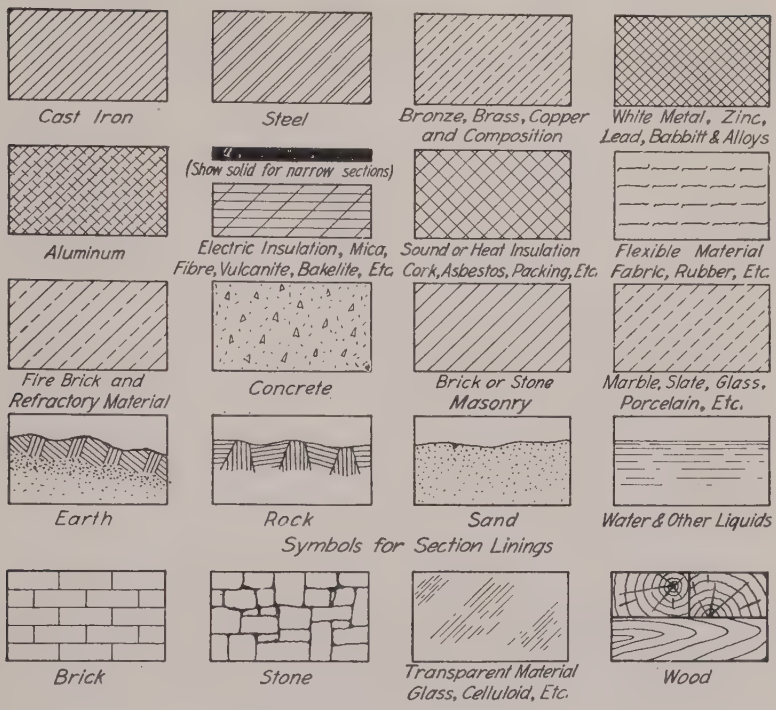


Fig. 147.—Symbols for materials.

ings involve the use of a large number of symbols or conventional representations, some of which are shown in Chap. XVI. For showing the cross section of long uniformly shaped pieces and for "breaking out" parts, the representations of Fig. 148 are used.

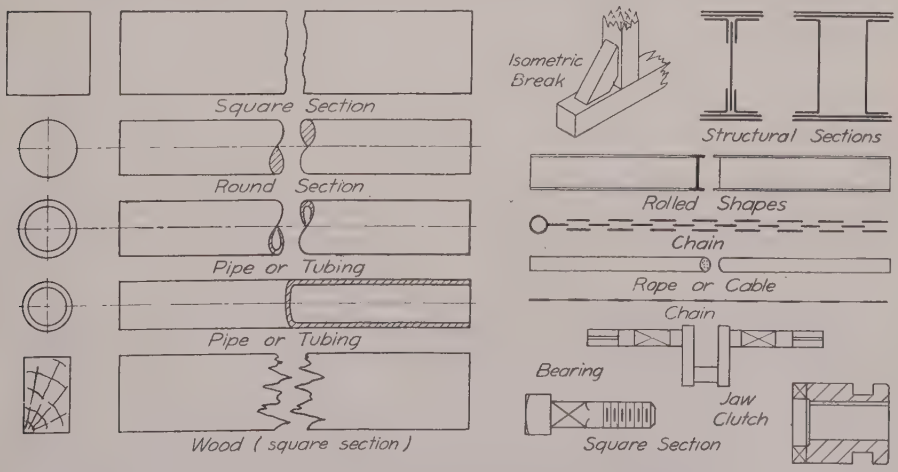


Fig. 148.—Conventional breaks and other symbols.

84. Titles.—Every sketch and drawing must have some kind of title. The form, completeness and location vary. On working drawings the title is usually "boxed" in the lower right-hand corner (Fig. 149) or as a part of a record strip extending across the bottom or end of the sheet (Fig. 150).

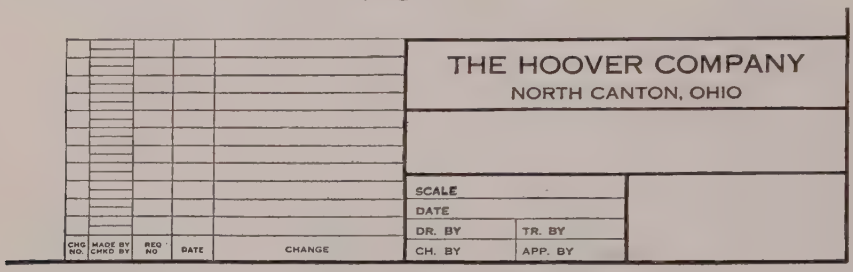


FIG. 149.—A boxed title.

The title gives as much as is necessary of the following information:

1. The name of the construction.
2. The name of the part shown (or simply "details").
3. Manufacturer; company or firm name and address.
4. Date; usually date of completion of tracing.
5. Scale, or scales.
6. Drafting-room record; names or initials with dates, of draftsman, tracer, checker, and approval of chief draftsman, engineer or superintendent.
7. Numbers of the drawing, of the shop order or of customer's order, according to system used.

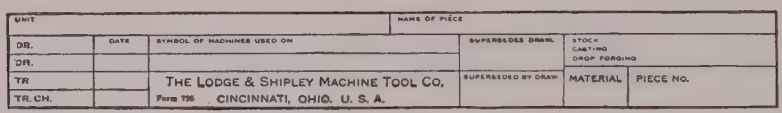


FIG. 150.—A record strip title.

In large drafting rooms the title is generally printed in blank on the paper or cloth used.

85. Bill of Material.—Drawings may have the name of the part, material, number required, part number, etc., given in a note near the views of each part. Another method often used is to place the number of the part in a circle near the views and then collect all the information in a tabulated list called a "bill of material" or "material list." This list is placed on the drawing over the title, or sometimes it is typewritten on a separate sheet. If the drawing is for wood construction, the bill will give the stock sizes, kind and quality of wood, board measure and number required of each part. Bolts and other metal parts are often specified and marked with the identification number or mark.

86. Blue Printing.—Much of the work in shops or on structures is done from blue prints, which are copies made from a tracing, on chemically treated paper, giving white lines on a blue background. As many copies as desired can be made from a single tracing. Blue prints can be made from pencil or ink drawings on tracing cloth, tracing paper or bond paper. The original drawing is never allowed to go into the shop but is kept in the files of the drawing room. Blue-print paper is usually bought ready sensitized and may be had in different degrees of rapidity. When fresh, it is of a yellowish green color, and an unexposed piece

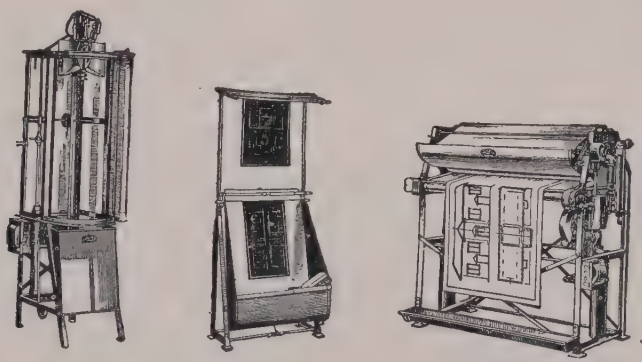


FIG. 151.—A vertical blue-print machine, washer and dryer.

should wash out perfectly white; with age or exposure to light or air, it turns to a darker gray-blue color and spoils altogether in a comparatively short time.

87. To Make a Blue Print.—Blue prints can be made by sunlight by using a framed glass with removable back, but more uniform results are obtained with an electric blue-print machine. One form, as made by the C. F. Pease Company for school use, is illustrated in Fig. 151 with washing and drying apparatus.

A print is made by placing the tracing with inked side against the glass cylinder and then a sheet of blue-print paper with sensitized side next to the tracing. These are held securely in position by a curtain which is rolled over them and clamped. The electric lamp is now turned on and allowed to fall slowly inside the glass cylinder. The time required to make a print varies from half a minute to several minutes, depending upon the sensitiveness of the paper. The yellowish-green color of the unexposed paper will turn to a grayish color. Take the paper from the machine and wash in a bath of running water for five or ten minutes. This fixes blue color and washes the lines to a

clear white. Hang up until dry. The prints may be improved in color and clearness by dipping in a dilute bath of sodium or potassium bichromate and rinsing after taking from the original bath. Changes may be made on blue prints by using an alkaline solution in a writing or drawing pen.

Other methods of reproducing drawings include Van Dyke paper, which gives white lines on a dark-brown background, and a number of special papers that give dark or black lines on a white background. Van Dyke negatives are used to make positive blue or black prints.

A number of companies reproduce tracings by various transfer processes. *Photostat* prints are used to a very considerable extent, especially when reduced-size copies are desired.

Nineteen Nevers

1. **Never** begin work without wiping off table and instruments.
2. **Never** use the scale as a ruler.
3. **Never** use a dull lead pencil.
4. **Never** draw with the lower edge of the T-square.
5. **Never** put either end of a pencil into the mouth.
6. **Never** take dimensions by setting the dividers on the scale.
7. **Never** run backward over a line with either pencil or pen.
8. **Never** try to use the same thumb-tack holes when putting paper or cloth down a second time.
9. **Never** use a blotter on inked lines.
10. **Never** leave the ink bottle uncorked.
11. **Never** dilute ink with water. If it is too thick, throw it away.
12. **Never** put a writing pen which has been used in ordinary writing ink into the drawing-ink bottle.
13. **Never** scrub a drawing all over with the eraser after finishing. It takes the life out of the inked lines.
14. **Never** cut paper with a knife and the edge of the T-square as a guide.
15. **Never** use the T-square as a hammer.
16. **Never** jab the dividers into the drawing board.
17. **Never** use the dividers as reamers or pincers or picks.
18. **Never** put instruments away without cleaning. This applies with particular force to pens.
19. **Never** put bow instruments away without opening to relieve the spring.

CHAPTER X

BOLTS, SCREWS AND OTHER FASTENINGS

The application of drafting to engineering uses requires a familiarity with certain elements, more or less common in mechanical practice, which form a part of machinery in general. Many such machine details are standardized, as bolts, nuts and screws (Fig. 152), keys, shafting, etc. Other details are partly standardized, and most of them, through theory and practical use, have developed rather well-defined characteristics and nomenclature.

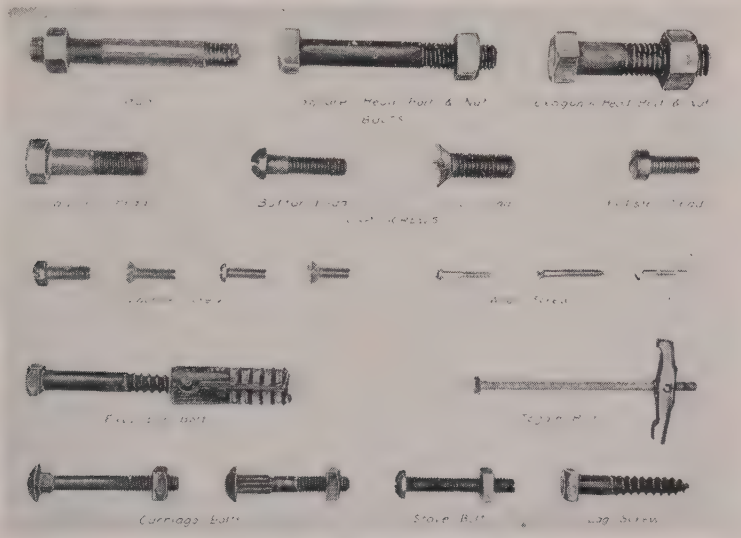


FIG. 152.—Threaded fastenings.

88. Screw Threads.—The use of screw threads is so frequent that the common forms and methods of representation must be understood. The most familiar occurrence of screw threads is on the ordinary wood screw and common bolt (Figs. 153 and 154).

The form of thread generally used in this country for most purposes is the American Standard, shown in Fig. 155. Wood-screw threads have a space between them to allow for the difference in strength of wood and metal. Other forms of threads used to meet various requirements are illustrated and named in the figure, which shows longitudinal sections.

To draw a true representation of a screw thread, it is necessary to draw the projection of a cylindrical helix. A cylindrical helix is a curve generated by moving a point uniformly around a cylinder and uniformly lengthwise of the cylinder at the same

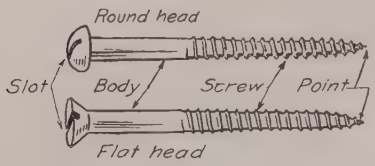


Fig. 153.—Wood screws.

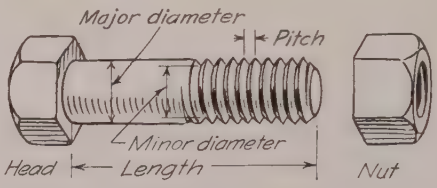


Fig. 154.—Hexagonal-head bolt and nut.

time. The hypotenuse of a right triangle will form one turn of a helix if it is wrapped around a cylinder, as in Fig. 156. The base of the triangle is equal to the circumference of the cylinder, and the altitude is the pitch of the helix, as shown at the top of Fig. 157.

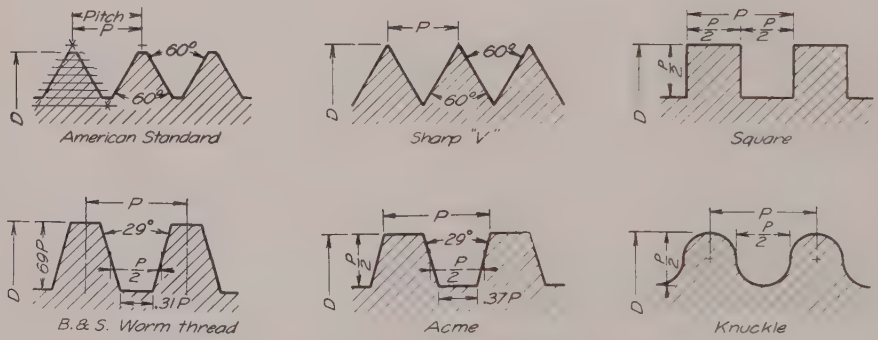


Fig. 155.—Thread profiles.

89. To Draw the Projection of a Helix. Draw two projections of a cylinder, divide the circumference of the top view into a number of equal parts and the pitch into the same number of equal parts, as at *A* (Fig. 157). From each point in the top view, drop perpendiculars to meet horizontal lines drawn through corresponding divisions of the front view. A smooth curve drawn through the points found will give the projection of the helix, as at *B* (Fig. 157). The application of the helix is shown at *C* (Fig. 157), which is the actual projection of a square thread. Such drawings are seldom made, since they require too much time and are no better practically than the conventional representations commonly used. For diameters of more than one inch, the

representations of Fig. 158 may be used. The order of drawing the lines for V threads is shown in Fig. 159.

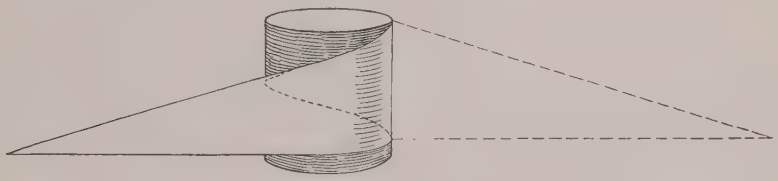


FIG. 156.—Picture of a helix.

90. Thread Symbols.—For small diameters the representation is further conventionalized to one of the forms of Fig. 160 which

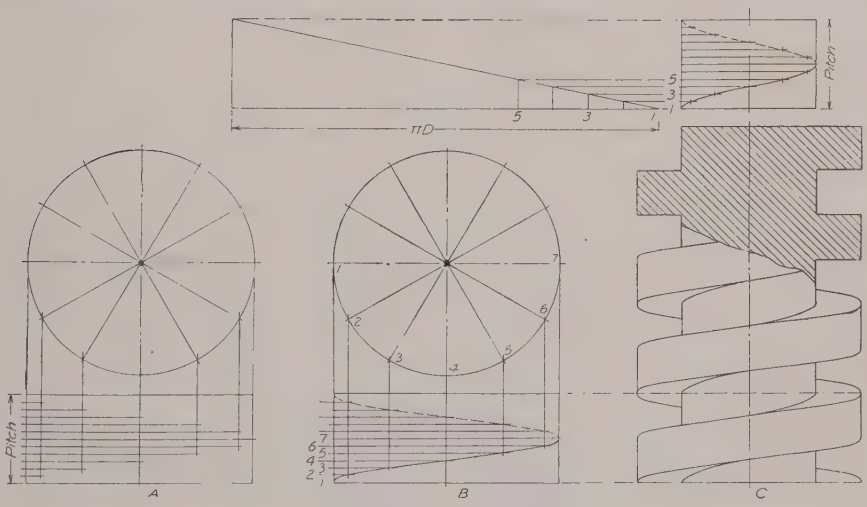


FIG. 157.—Helix and square thread.

shows external threads. American Standard symbols are given at *A*, *B*, *C* and *D* and are recommended for general use. Note the

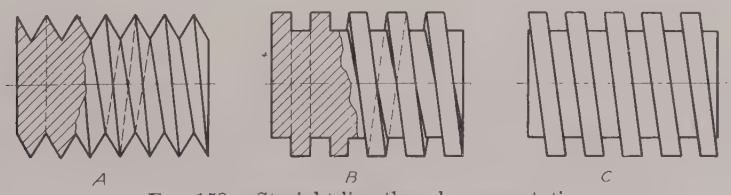


FIG. 158.—Straight-line thread representation.

light and heavy lines at *A* to represent the crests and roots of the thread. At *E* and *F* are shown two representations which have been much used and which will be seen on many shop drawings.

At F the slope of the lines is equal to one-half the assumed pitch. The actual pitch is not measured, but the lines are spaced by eye to look well.

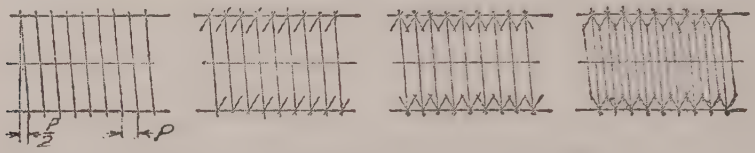


FIG. 159.—Stages in drawing a V thread.

American Standard symbols for internal threads (threaded holes) in section and in elevation and plan are given in Fig. 161. The simplified methods at D, E and F are used to save time on details of separate parts but should not be used on views of assembled parts.

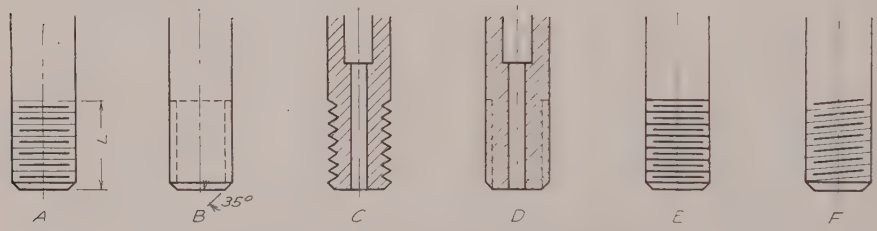


FIG. 160.—External thread representations.

A small threaded hole is called a "tapped" hole and a note, such as tap ½"-13NC-2, is used on the drawing (see Art. 94).

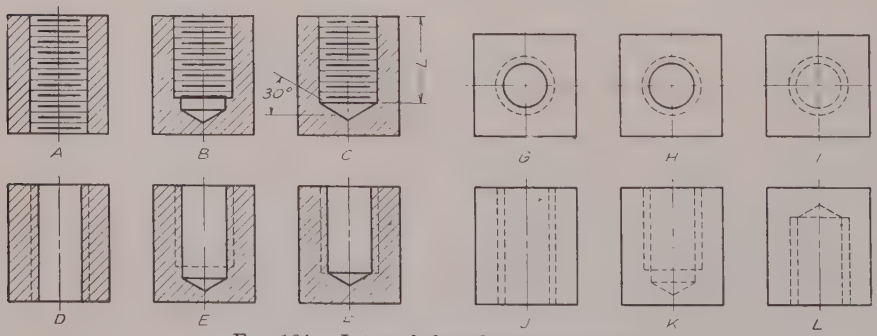


FIG. 161.—Internal thread representations.

If a threaded hole does not go clear through a piece, the "drill point" or shape of the bottom of the hole should be drawn with the angle as at C. Screw threads in section are shown in Fig. 162.

91. Bolts and Other Fastenings.—The various kinds of bolts, screws and rivets used for fastening parts together occur on so many drawings that the draftsman must know what kind of fastenings to use and how to represent them. In the previous paragraphs the methods of representing threads conventionally have been shown. These are always used on shop drawings because of the saving of time.

There are many forms of threaded fastenings made for different purposes. The ones which we must be familiar with include the American Standard hexagon-head and square-head bolts and nuts. The number of threads per inch is standard for each diameter in each of the standard series.

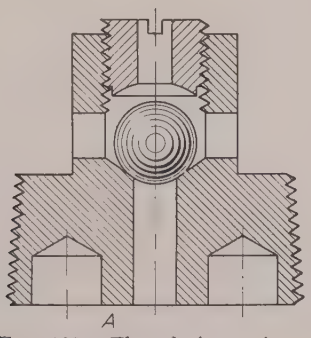


FIG. 162.—Threads in section.

The material presented is based upon the report of the American Standards Association on Screw Threads and on Wrench Head Bolts and Nuts. Sufficient information is included to enable the student to make use of American Standards for his drawings.

92. American Standard Screw Threads.—The American (National) form of screw thread is shown in Fig. 155. Two series of pitches have been provided; they are known as American Coarse Thread Series and American Fine Thread Series. The first corresponds in part with the U. S. Standard which it replaces. The second corresponds in part with the S.A.E. Standard which it replaces. Table I gives some information for both series.

93. Names concerning screw threads are given in the report mentioned in Art. 91, from which the following are taken (Fig. 154). The large or outside diameter is called the *major diameter*. The small or inside diameter is called the *minor diameter*. The *pitch diameter* is "the diameter of an imaginary cylinder the surface

of which would pass through the threads at such points as to make equal the width of the spaces cut by the cylinder."

TABLE I.—AMERICAN STANDARD COARSE AND FINE THREADS
With Minor Diameters for Tap-drill Sizes

Diameter	Threads per inch		Tap drill sizes		Diameter	Threads per inch		Tap drill sizes	
	Coarse NC	Fine NF	Coarse NC	Fine NF		Coarse NC	Fine NF	Coarse NC	Fine NF
1/4	20	28	0.1959	0.2113	1 1/4	7	12	1.0954	1.1598
5/16	18	24	0.2524	0.2674	1 3/8	6	12	1.1946	1.2848
3/8	16	24	0.3073	0.3299	1 1/2	6	12	1.3196	1.4098
7/16	14	20	0.3602	0.3834	1 3/4	5		1.5335	
1/2	13	20	0.4167	0.4459	2	4 1/2		1.7594	
9/16	12	18	0.4723	0.5024	2 1/4	4 1/2		2.0094	
5/8	11	18	0.5266	0.5649	2 1/2	4		2.2294	
3/4	10	16	0.6417	0.6823	2 3/4	4		2.4794	
7/8	9	14	0.7547	0.7977	3	4		2.7294	
1	8	14	0.8647	0.9227	3 1/4	4		2.9794	
1 1/8	7	12	0.9704	1.0348	3 1/2	4		3.2294	
					3 3/4	4		3.4794	
					4	4		3.7294	

Classes of Fits.—Four classes of screw-thread fits are given in the American Standards and described in detail with dimensions, tolerances, etc., in the report. The four classes are:

Loose Fit (*Class* 1).—Recommended as a commercial standard for tapped holes in the numbered sizes only. May be used with screws of other classes to obtain quality of fit desired.

Free Fit (*Class* 2).—Includes the great bulk of screw-thread work of ordinary quality of finished and semi-finished bolts and nuts, etc.

Medium Fit (*Class* 3).—Includes the better grade of interchangeable screw-thread work, such as automobile bolts and nuts.

Close Fit (*Class* 4).—Includes screw-thread work requiring a fine snug fit, somewhat closer than the medium fit, such as high-grade aircraft parts, etc. In this class of fit selective assembly of parts may be required.

94. Symbols for Specification. The American (National) Standard screw threads are specified by the following symbols: diameter (or screw number), number of threads per inch, initial letters of the series, as NC or NF and, finally, the class of fit. For 1¼″ diameter, six threads per inch, coarse thread, Class 2, the specification would read thus:

1¼″-6NC-2

If left-handed, the letters LH follow the number of threads.

95. To Draw a Hexagon.—Since the hexagonal form of bolt head and nut is used to such a large extent, we must know how to draw a regular hexagon. Given the distance between two sides, called the "short diameter," or "distance across flats" (Fig. 163): First draw horizontal and vertical center lines. With the intersection as a center, draw a circle having a diameter equal to the distance across flats. With the T-square and 30°–60° triangle, draw lines tangent to the circle in the order given.

A hexagonal bolt head is a hexagonal prism with the corners chamfered, as shown in the picture (Fig. 154).

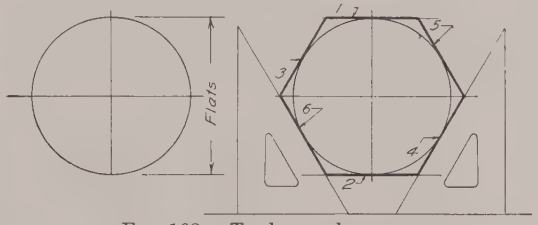


FIG. 163.—To draw a hexagon.

96. American Standard Wrench-head Bolts and Nuts.—There are two series of standards: *regular* and *heavy*. These two series are modified as to dimensions by the extent of the machined surfaces, if any, for which the following terms are used:

Unfinished—not machined on any surface.
Semi-finished—machined on bearing surface only.
Finished—machined all over.

For complete tables of dimensions and other detail information the report of the American Standards Association, entitled "Wrench-Head Bolts and Nuts and Wrench Openings," should be secured. The information contained in this chapter will be found sufficient for drawing purposes.

97. Regular Bolt Heads and Nuts.—For drawing purposes the general dimensions may be taken, as given in Fig. 164. Width across flats of hexagon or square equals $1\frac{1}{2}D$ adjusted to sixteenths. Height of bolt head equals $\frac{2}{3}D$ adjusted to fractions. Nominal thickness of nut equals $\frac{7}{8}D$. The chamfer angle with the top may be drawn at 30° for either hexagon or square forms. The radii for the arcs can be found by trial to suit the conditions shown.

Semi-finished square and hexagon bolt heads and nuts may have plain or "washer-face" bearing surfaces (Fig. 165).

TABLE II.—AMERICAN STANDARD REGULAR SQUARE AND HEXAGON BOLT HEADS AND NUTS

Nominal Dimensions

Diameter of bolt D	Bolt heads						Nuts			
	Unfinished		Semi-finished		Finished		Unfinished and finished		Semi-finished	
	Flats	Height	Flats	Height	Flats	Height	Flats	Thick-ness	Flats	Thick-ness
1/4	3/8	11/64	3/8	5/32	7/16	3/16	7/16	7/32	7/16	13/64
5/16	1/2	13/64	1/2	3/16	9/16	15/64	9/16	17/64	9/16	1/4
3/8	9/16	1/4	9/16	15/64	5/8	9/32	5/8	21/64	5/8	5/16
7/16	5/8	19/64	5/8	9/32	3/4	21/64	3/4	3/8	3/4	23/64
1/2	3/4	21/64	3/4	19/64	13/16	3/8	13/16	7/16	13/16	27/64
9/16	7/8	3/8	7/8	11/32	7/8	27/64	7/8	1/2	7/8	15/32
5/8	15/16	27/64	15/16	25/64	1	15/32	1	35/64	1	17/32
3/4	1 1/8	1/2	1 1/8	15/32	1 1/8	9/16	1 1/8	21/32	1 1/8	41/64
7/8	1 5/16	19/32	1 5/16	9/16	1 5/16	21/32	1 5/16	49/64	1 5/16	3/4
1	1 1/2	21/32	1 1/2	19/32	1 1/2	3/4	1 1/2	7/8	1 1/2	55/64
1 1/8	1 11/16	3/4	1 11/16	11/16	1 11/16	27/32	1 11/16	1	1 11/16	31/32
1 1/4	1 7/8	27/32	1 7/8	25/32	1 7/8	15/16	1 7/8	1 3/32	1 7/8	1 1/32
1 3/8	2 1/16	29/32	2 1/16	27/32	2 1/16	1 1/32	2 1/16	1 13/64	2 1/16	1 9/64
1 1/2	2 1/4	1	2 1/4	15/16	2 1/4	1 1/8	2 1/4	1 5/16	2 1/4	1 1/4
1 5/8	2 7/16	1 3/32	2 7/16	1 1/32	2 7/16	1 7/32	2 7/16	1 27/64	2 7/16	1 23/64
1 3/4	2 5/8	1 5/32	2 5/8	1 3/32	2 5/8	1 5/16	2 5/8	1 17/32	2 5/8	1 15/32
1 7/8	2 13/16	1 1/4	2 13/16	1 3/16	2 13/16	1 13/32	2 13/16	1 41/64	2 13/16	1 37/64
2	3	1 11/32	3	1 7/32	3	1 1/2	3	1 3/4	3	1 11/16
2 1/4	3 3/8	1 1/2	3 3/8	1 3/8	3 3/8	1 11/16	3 3/8	1 31/32	3 3/8	1 29/32
2 1/2	3 3/4	1 21/32	3 3/4	1 17/32	3 3/4*	1 7/8	3 3/4	2 3/16	3 3/4	2 3/32
2 3/4	4 1/8	1 53/64	4 1/8	1 11/16	4 1/8	2 1/16	4 1/8	2 13/32	4 1/8	2 5/16
3	4 1/2	2	4 1/2	1 7/8	4 1/2	2 1/4	4 1/2	2 5/8	4 1/2	2 17/32

Finished hexagon bolt heads and nuts have "washer-face" bearing surfaces and a greater thickness of head ($\frac{3}{4}D$), as shown in Fig. 166.

Some dimensions for American Standard Regular bolt heads and nuts are given in Table II.

98. Heavy Bolt Heads and Nuts.—This series is for use where a greater bearing surface is required and so is somewhat larger than the regular series. As indicated in Fig. 167 the distance across flats for the unfinished square and hexagon bolt heads and nuts is $1\frac{1}{2}D + \frac{1}{8}''$. The height of the head is $\frac{3}{4}D + \frac{1}{16}''$,

and the thickness of the nut is made equal to D. There are slight differences in some of the dimensions for the semi-finished square and hexagon and for the finished hexagon bolt heads and nuts.

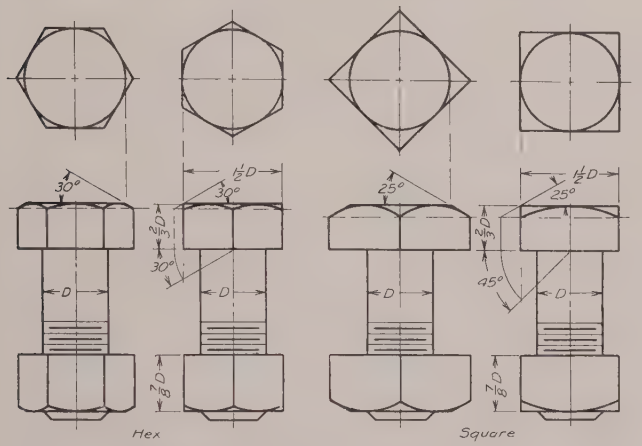


Fig. 164. Fig. 165.

Fig. 164.—American Standard regular, unfinished, bolt heads and nuts (for drawing purposes).

Fig. 165.—American Standard regular, semi-finished, washer faced bolt heads and nuts.

The proportions given in Fig. 167 are satisfactory for drawing purposes. Full details, if required, can be obtained from the American Standards report mentioned in Art. 96.

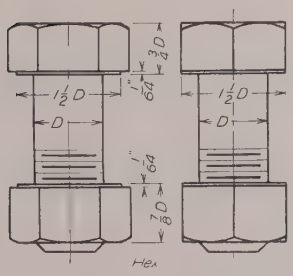


Fig. 166.—American Standard regular, finished bolt heads and nuts.

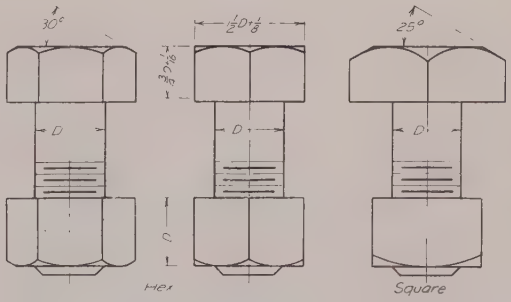


Fig. 167.—American Standard heavy bolt heads and nuts.

99. To Draw an American Standard Hexagon Bolt Head. Start the top view (Fig. 168) by drawing the chamfer circle with a diameter equal to one and one-half times the diameter of the bolt. About this circle draw a hexagon as described in Art. 95. For the front view draw a horizontal line representing the under surface of the head. The height of the head is $\frac{2}{3}D$. Draw the top line and project from the top view to obtain the vertical edges.

Project diameter of chamfer circle and draw 30° chamfer lines as shown. Drawing will appear as at *A*, Fig. 168. Draw lines 1, 2, 3, 4, to locate chamfer intersections as at *B*. Radius R_1 can be found by trial so that arc will pass through points 2 and 3 and be tangent to top line. Complete the front view as at *C* by drawing arcs with radii R_2 (tangent to top line and through points 1, 2 at left and 3, 4 at right, by trial).

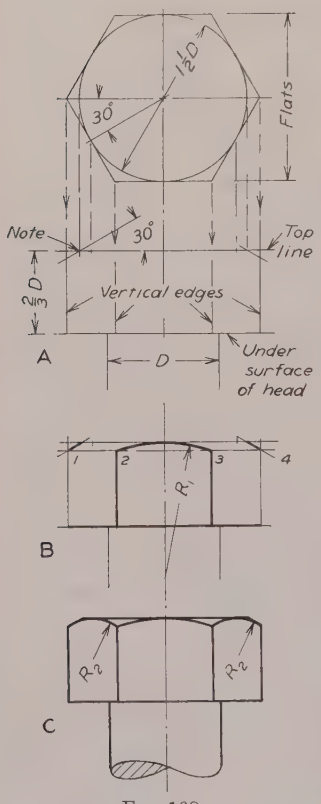


Fig. 168.

100. Bolts and Studs.—The proportions of bolt heads and nuts are so well standardized that they are not dimensioned on a drawing. For a standard bolt it is necessary to specify only two dimensions, the diameter and length from under the surface of head to end of bolt, as in Fig. 169. If standard minimum length of thread is not used, length of thread from end of bolt must be added.

A **stud** or stud bolt (Fig. 170) has threads on both ends and is used where bolts are not suitable and for parts which must be removed often. One end is screwed permanently into a tapped hole, and a nut is screwed on to the projecting end.

A threaded or tapped hole may be dimensioned as in Fig. 171, or a note may be used.

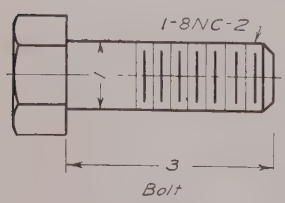


Fig. 169.—Bolt.

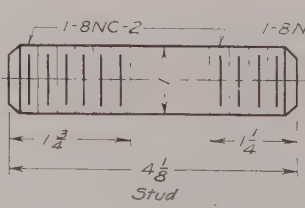


Fig. 170.—Stud.

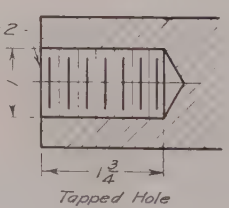


Fig. 171.—Tapped hole.

Various arrangements are used to prevent nuts from working loose under vibration. Many patented devices are available.

Lock nuts, such as that illustrated in Fig. 172, are probably the commonest means of holding the nut in place. American Standard jam nuts have the same distance across flats as the unfinished, semi-finished and finished nuts with thicknesses of Table III.

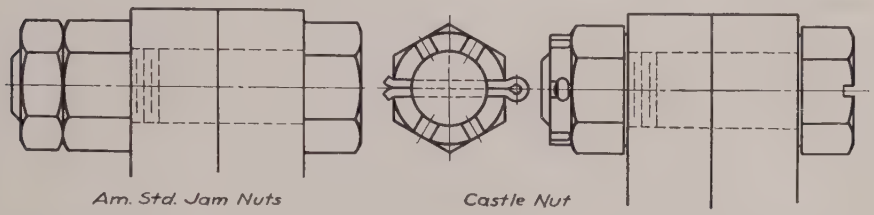


FIG. 172.—Lock nuts.

TABLE III.—AMERICAN STANDARD JAM NUTS

Diameter	Thickness	
	Unfinished and finished	Semi-finished
¼ to 7/16	$\frac{1}{2}D + \frac{1}{32}$	$\frac{1}{2}D + \frac{1}{64}$
½ to 1⅛	$\frac{1}{2}D + \frac{1}{16}$	$\frac{1}{2}D + \frac{3}{64}$
1¼ to 2¼	$\frac{1}{2}D + \frac{1}{8}$	$\frac{1}{2}D + \frac{1}{16}$
2½ to 3	$\frac{1}{2}D + \frac{1}{4}$	$\frac{1}{2}D + \frac{5}{32}$

101. Cap Screws.—Cap screws are used for fastening two pieces together by passing through one and screwing into the other. Some forms of American Standard cap screws are illustrated in Fig. 173. Dimensions for hexagon-head cap screws are given in Table IV and some general dimensions for the other forms in Table V.

102. Machine screws are used where small diameters are required. They are specified by number. Some American Standard machine screws are shown in Fig. 174, with dimensions in Table VI.

103. Set screws (Fig. 175) are used for holding two parts in a desired position relative to each other by screwing through a threaded hole in one piece and bearing against the other. Some dimensions for American Standard square-head set screws are given in Table VII.

104. Wood screws are made of steel, brass or aluminum and are finished in various ways. Steel screws may be bright (natural finish), blued, galvanized or copper-plated, while both steel and brass are sometimes nickel-plated. Round-head screws have the

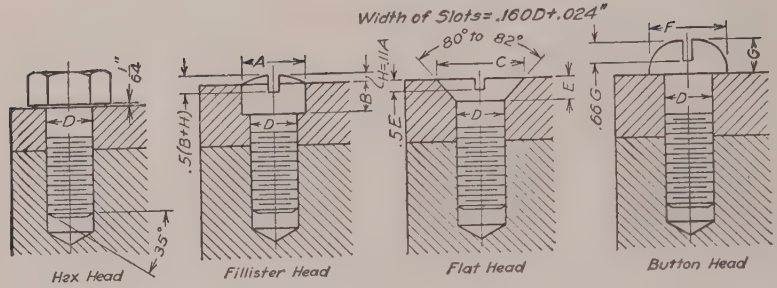


FIG. 173.—Cap screws.

TABLE IV.—AMERICAN STANDARD HEXAGON-HEAD CAP SCREWS

Diameter *D*	Threads per inch, coarse	Width across flats *W*	Height of head *H*
1/4	20	7/16	3/16
5/16	18	1/2	15/64
3/8	16	9/16	9/32
7/16	14	5/8	21/64
1/2	13	3/4	3/8
9/16	12	13/16	27/64
5/8	11	7/8	15/32
3/4	10	1	9/16
7/8	9	1 1/8	21/32
1	8	1 5/16	3/4
1 1/8	7	1 1/2	27/32
1 1/4	7	1 11/16	15/16

TABLE V.—AMERICAN STANDARD SLOTTED-HEAD CAP SCREWS

Diameter *D*	1/4	5/16	3/8	7/16	1/2	9/16	5/8	3/4	7/8	1
A	3/8	7/16	9/16	5/8	3/4	13/16	7/8	1	1 1/8	1 15/16
B	11/64	13/64	1/4	19/64	21/64	3/8	27/64	1/2	19/32	21/32
C	1/2	5/8	3/4	13/16	7/8	1	1 1/8	1 3/8		
E	.146	.183	.220	.220	.220	.256	.293	.366		
F	7/16	9/16	5/8	3/4	13/16	15/16	1	1 1/4		
G	.191	.246	.273	.328	.355	.410	.438	.547		

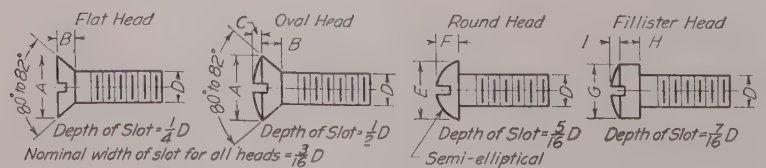


FIG. 174.—Machine screws.

TABLE VI.—AMERICAN STANDARD MACHINE SCREWS
Maximum Dimensions

Nominal size	2	3	4	5	6	8	10	12	¼	5/16	⅜
D = diameter	.086	.099	.112	.125	.138	.164	.190	.216	.250	.3125	.375
Threads per inch (coarse)	56	48	40	40	32	32	24	24	20	18	16
Threads per inch (fine)	64	56	48	44	40	36	32	28	28	24	24
A	.172	.199	.225	.252	.279	.332	.385	.438	.507	.636	.762
B	.051	.059	.067	.075	.083	.100	.116	.132	.153	.192	.230
C	.029	.033	.037	.041	.045	.053	.061	.069	.079	.098	.117
E	.162	.187	.211	.236	.260	.309	.359	.408	.472	.591	.708
F	.070	.078	.086	.095	.103	.119	.136	.152	.174	.214	.254
G	.140	.161	.183	.205	.226	.270	.313	.357	.414	.519	.622
H	.055	.063	.072	.081	.089	.106	.123	.141	.163	.205	.246
I	.028	.032	.035	.039	.043	.050	.057	.064	.074	.092	.109

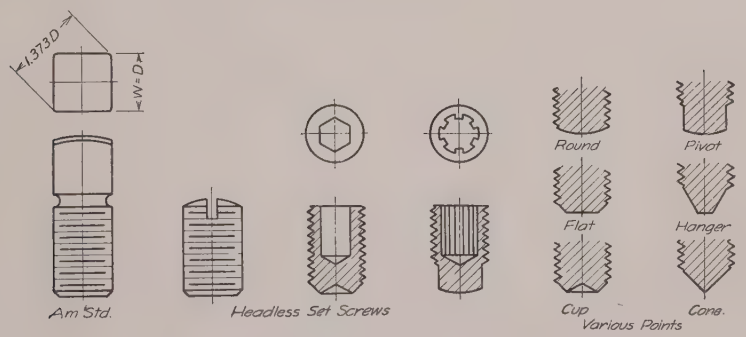


FIG. 175.—Set screws.

TABLE VII.—AMERICAN STANDARD SQUARE-HEAD SET SCREWS

Diameter *D*	Threads per inch (either coarse or fine)		Width across flats *W*	Height of head *H*
	Coarse	Fine		
¼	20	28	¼	3/16
5/16	18	24	5/16	15/64
⅜	16	24	⅜	9/32
7/16	14	20	7/16	21/64
½	13	20	½	⅜
9/16	12	18	9/16	27/64
⅝	11	18	⅝	15/32
¾	10	16	¾	9/16
⅞	9	14	⅞	21/32
1	8	14	1	¾
1⅛	7	12	1⅛	27/32
1¼	7	12	1¼	15/16
1½	6	12	1½	1 ⅛

head above the wood, while flat-head screws are set flush or countersunk. They are drawn as in Fig. 176. Wood screws are specified by number, length, style of head and finish. Length of flat-head

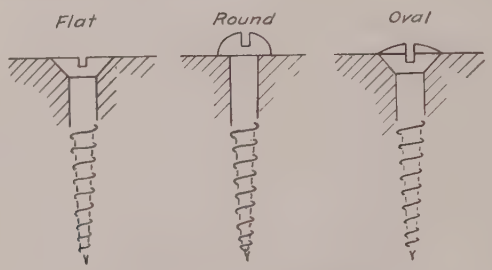


Fig. 176.—Wood screws.

screws is measured over all, round-head screws from under head to point and oval-head screws from largest diameter of countersink to point. Diameters of American Standard wood screws are as follows:

Screw number....	0	1	2	3	4	5	6	7	8
Diameter.....	.060	.073	.086	.099	.112	.125	.138	.151	.164
Screw number....	9	10	11	12	14	16	18	20	24
Diameter.....	.177	.190	.203	.216	.242	.268	.294	.320	.372

105. A lag screw, drawn as in Fig. 177, is used for fastening machinery to wood supports and for heavy wood constructions when a bolt cannot be used. It is similar to a regular bolt but has wood-screw threads. The head may be either square or hexagonal. Lag screws are specified by diameter and length from under surface of head to end of screw.

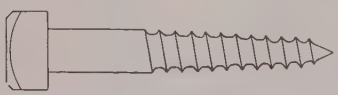


Fig. 177.—Lag screw.

Several other forms of screws and bolts are drawn as in Fig. 178. Screw hooks and screw eyes are specified by diameter and length over all.

106. Keys.—Pulleys, flywheels, cranks and similar parts are generally secured to their shaft by some form of key (Fig. 179). The style of key is selected to fit the duty which it must perform, ranging from the saddle key for light duty to special forms or two square keys for heavy duty. The common sunk key may have a breadth of about one-fourth the shaft diameter and a thickness of

from five-eighths the breadth to same as breadth. The Woodruff key is much used in machine-tool work. It is made in standard sizes and specified by number (see engineering handbooks).

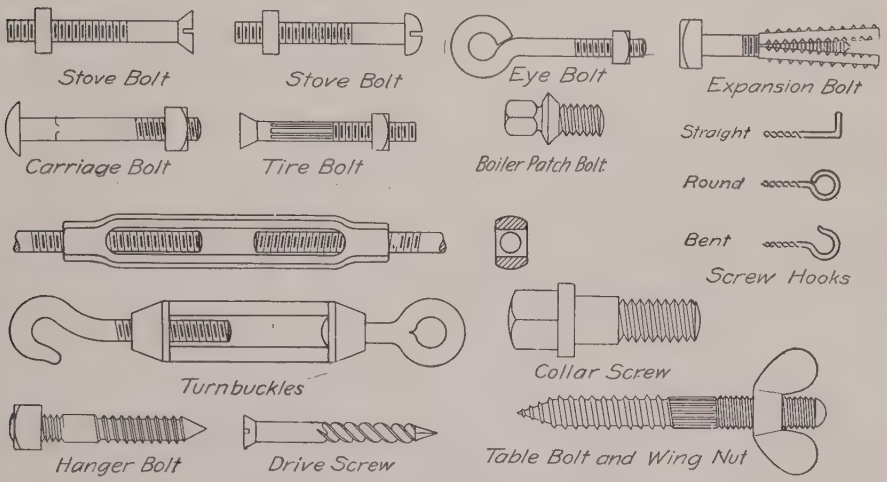


FIG. 178.—Various bolts and screws.

107. Rivets.—Sheet-metal plates, structural-steel shapes and many other parts are put together with rivets, especially when permanent fastenings are desired.

Structural rivets have the forms shown in Fig. 180. Boiler and tank rivets have the forms shown in Fig. 181.

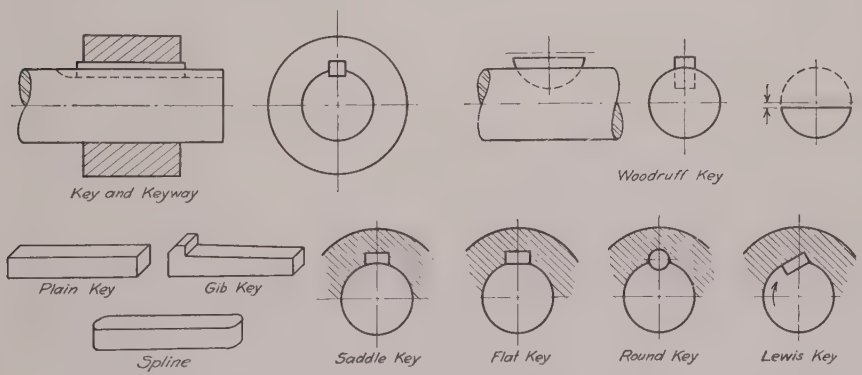


FIG. 179.—Keys.

American Standard small rivets, $\frac{3}{32}''$ to $\frac{7}{16}''$ diameter, are made with a variety of heads (Fig. 182).

108. Welding.—Mechanical and structural engineers are making an increasing use of welding for building up and fastening parts together. Standard steel shapes, plates and bars may be welded

together to make machine frames and other parts that have been made of cast iron in the past. The greater strength of steel in tension is often an advantage that permits a design of less weight

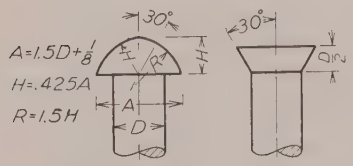


Fig. 180.—Structural rivets.

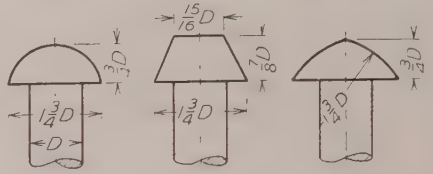


Fig. 181.—Boiler rivets.

and complication than cast iron. Sheet-metal work, as tanks and other containers, can be simplified by welding instead of riveting the joints.

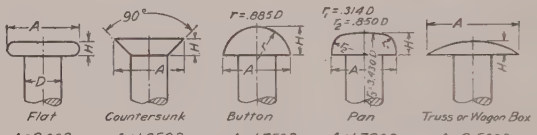


Fig. 182.—American Standard small rivets.

A few welding representations for use on drawings are shown in Fig. 183. Either symbols or notes may be used. A continuous weld may be shown by the symbol at *A* or more usually by a note, as at *B*. The symbol at *C* represents a ¼″ intermittent weld on

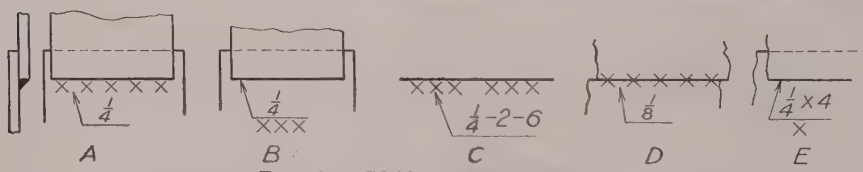


Fig. 183.—Welding representations.

the near side of the joint with increments 2″ long, spaced 6″ center to center. The symbol at *D* represents a butt weld with reinforcement on near side, ⅛″ deep. The note at *E* specifies a single-row spot weld, with ¼″ diameter spots, spaced 4″ centers.

CHAPTER XI

MECHANICAL DRAFTING

109. Drafting Practice.—A working drawing is a drawing which completely describes the shape and size and gives specifications for the kinds of material, methods of finish, accuracy required and all other information necessary for making a single part or a complete machine or structure. A picture and working drawing of a simple machine part are shown in Fig. 184.

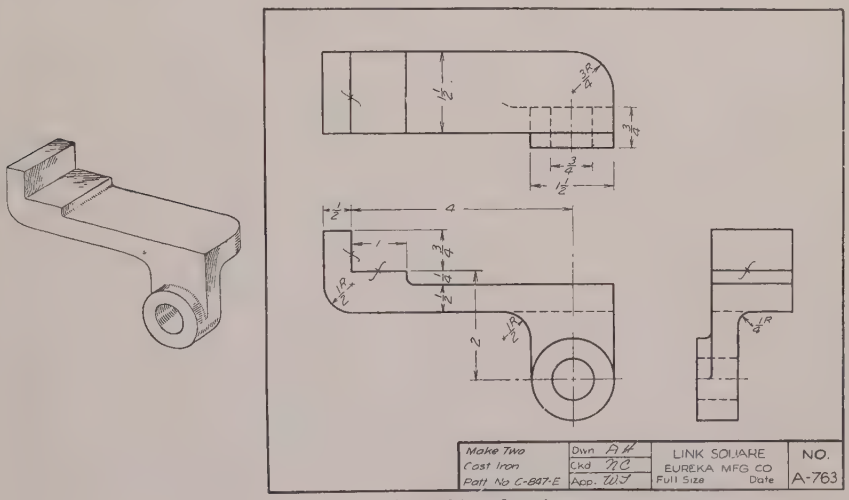


FIG. 184.—A working drawing.

110. Working drawings are based upon orthographic projection (Chap. IV) with dimensions and notes added as described in Chaps. VIII, IX and X.

Such drawings must conform in style with good practice as followed in the office where they are made. There must be contrast, obtained by giving proper values to the various lines which compose the views. Legible figures, uniform lettering and the use of standard terms are essential. When completed, a working drawing must be thoroughly checked for errors and improvements before being submitted for approval.

111. Detail Drawings.—A drawing of a single piece, which gives all the information necessary for making it, is called a "detail drawing." This is the simplest form of working drawing and must be a complete and accurate description of the piece, with carefully selected views and well-located dimensions. Sometimes separate detail drawings are made for the use of different workmen, as the patternmaker, blacksmith, machinist, welder, etc. Such drawings have only the dimensions and information needed by the workmen for whom the drawing is made. An ordinary machine detail drawing is shown in Fig. 185.

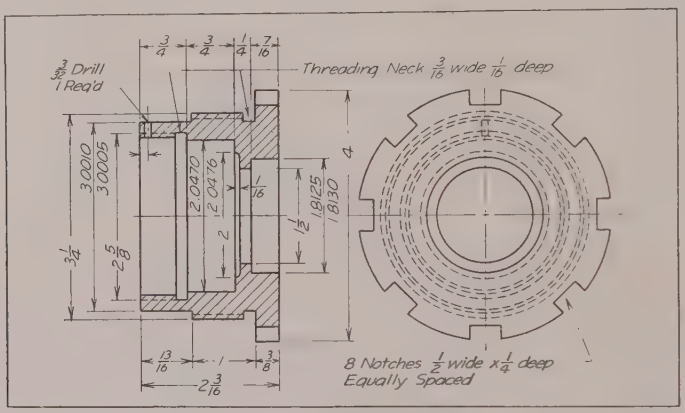


Fig. 185.—A detail drawing.

When a large number of machines are to be manufactured, it is usual to make a detail drawing for each part on a separate sheet.

The picture (Fig. 186) shows a forging as formed and after it has been machined. The working drawing of the Superspacer Latch Pinion, made by the Hartford Special Machinery Company, is shown in Fig. 187. Notice the representation of parts to be removed after all work is done and the detailed list of machine operations.

112. Assembly Drawings.—A drawing of a completely assembled construction is called an "assembly drawing." Such drawings vary greatly in regard to completeness of detail and dimensioning. Their particular value is in showing the way in which the parts go together and the appearance of the construction as a whole. When complete information is given, they may be used for working drawings. This is possible when there is little or no complex detail. Figure 188 shows such a drawing. Furniture

and other wood constructions can often be represented in assembly working drawings by adding necessary enlarged details or additional partial views.

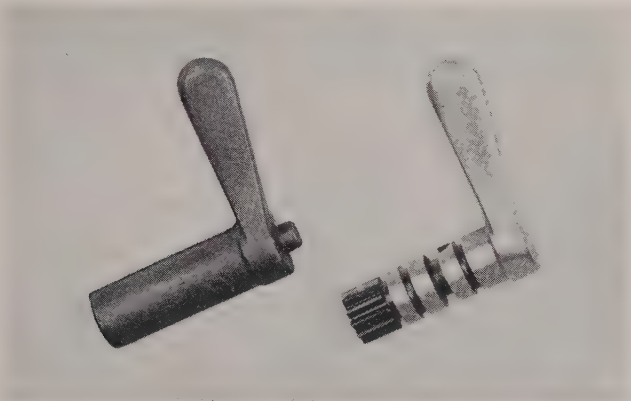


FIG. 186.—Index plunger operating handle (forging and finished part).

Assembly drawings of machines are generally made to small scale with selected dimensions to tell over-all distances, important

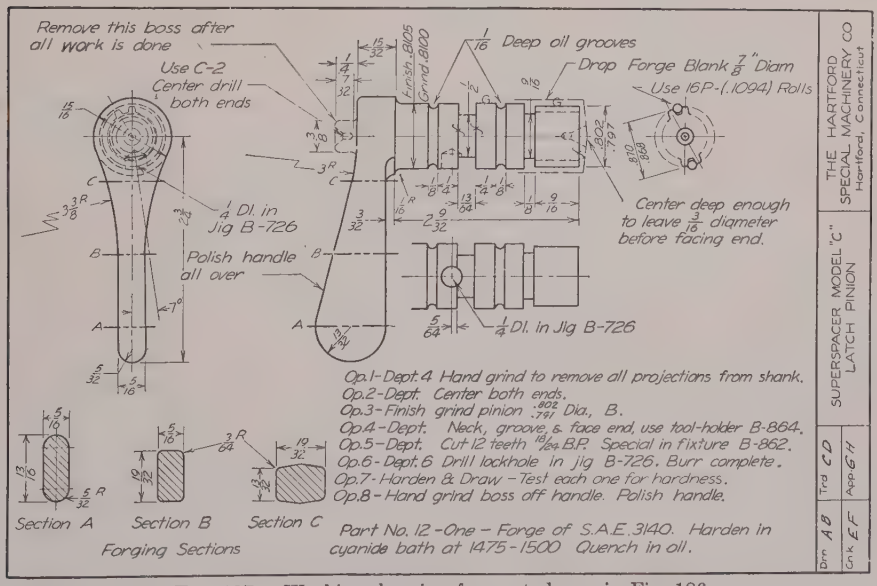

Remove this boss after all work is done
Use C-2 Center drill both ends
Finish .8105 Grind .8100
1/16 Deep oil grooves
Drop Forge Blank 7/8" Diam
Use 16P-(.1094) Rolls
1/4 Dl. in Jig B-726
Polish handle all over
Center deep enough to leave 3/16 diameter before facing end.
1/4 Dl. in Jig B-726
Op.1-Dept.4 Hand grind to remove all projections from shank.
Op.2-Dept. Center both ends.
Op.3-Finish grind pinion .902/.791 Dia., B.
Op.4-Dept. Neck, groove, & face end, use tool-holder B-864.
Op.5-Dept. Cut 12 teeth 19/64 D.P. Special in fixture B-862.
Op.6-Dept.6 Drill lockhole in jig B-726. Burr complete.
Op.7-Harden & Draw-Test each one for hardness.
Op.8-Hand grind boss off handle. Polish handle.
Section A
Section B
Section C
Forging Sections
Part No. 12-One-Forge of S.A.E.3140. Harden in cyanide bath at 1475-1500 Quench in oil.
THE HARTFORD SPECIAL MACHINERY CO Hartford, Connecticut
SUPERSPACER MODEL "C" LATCH PINION
Drn AB
Trd CD
Chk EF
App GH

FIG. 187.—Working drawing for part shown in Fig. 186.

center-to-center distances and location dimensions. All or almost all hidden lines may be left out and, if drawn to a very small scale, unnecessary detail may be omitted. Figure 189 is an example.

Either exterior or sectional views may be used. When the general appearance is the main purpose of the drawing, only one view or two views may be used.

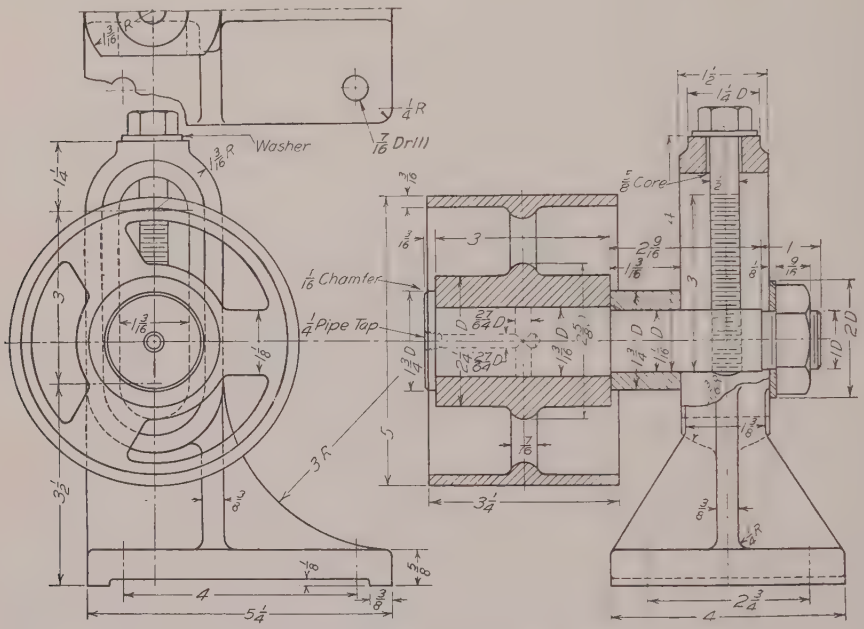


FIG. 188.—An assembly working drawing.

113. Choice of Views.—Much of the ease with which a drawing can be used depends upon proper selection of views. For the complete description of an object at least two views are required. While a drawing is not a picture, it is always advisable to select the views which require the least effort to read. Each view must have a part in the description; otherwise it is not needed and should not be drawn. In some cases one view is all that is necessary, provided a note is added or the shape and size are standard or evident. Complex pieces may require more than three views, some of which may be partial views, auxiliary views and sectional views. The reason for making the drawing must always be kept in mind when a question arises. The final test of the value of a drawing is its clearness and exactness in giving the complete information necessary for making the piece.

114. Choice of Scale.—The choice of scale for a detail drawing is governed by three things: the size necessary for showing all details clearly, the size necessary for carrying all dimensions with-

out crowding and the size of paper used. It is always desirable to make detail drawings to full size. Other scales commonly used are half, quarter and eighth (see Art. 14). Such scales as 2″ = 1′, 4″ = 1′ and 9″ = 1′ are to be avoided. If a part is very small, it is sometimes drawn to an enlarged scale, perhaps twice full size.

When a number of details are drawn on one sheet, they should if possible be to the same scale. If different scales are used, they should be noted near each drawing. A detail or part detail drawn to a larger scale may often be used to advantage on assembly drawings. This will save the making of separate detail drawings. General assembly drawings can be made to such a scale as will

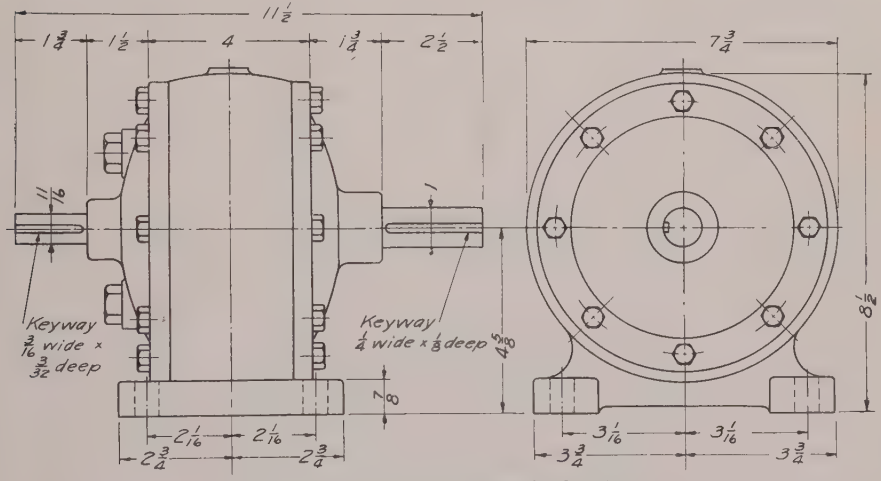


Fig. 189.—An outline assembly drawing.

show the desired amount of detail and work up well on the size of paper used. Sheet-metal pattern drawings for practical use are always made full size, although practice models may be constructed from small-scale layouts.

115. Grouping and Placing Parts.—When a number of details are used for one machine only, they are often grouped on a single sheet or set of sheets. A convenient arrangement is to group the forging details together, the brass details together and similarly for other materials. In general, it is well to represent parts in the position which they will have in the assembled machine, with related parts near each other. Long pieces, however, such as shafts and bolts, are drawn with their long dimensions parallel to the long dimension of the paper.

116. Conventional Representation.—The principles upon which the description of shape by means of views is based have been

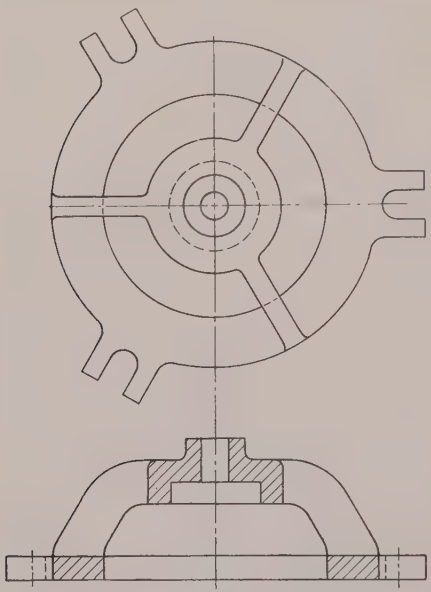


FIG. 190.—A symmetrical section.

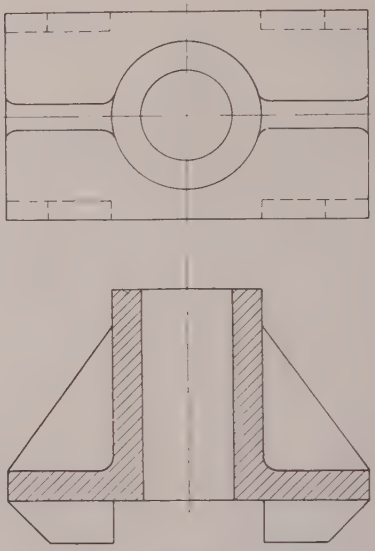


FIG. 191.—Rib in section.

explained and they form the basis for working drawings. In the actual use of mechanical drawing, it has been found desirable under certain conditions to violate the rules previously given.

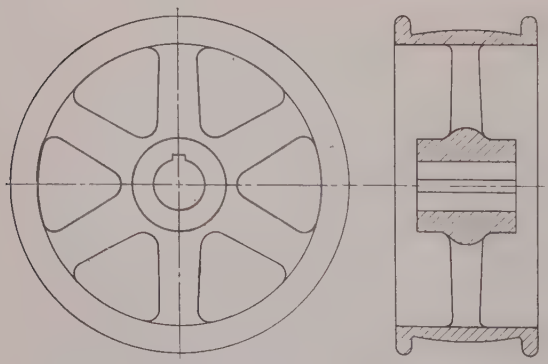


FIG. 192.—Pulley in section.

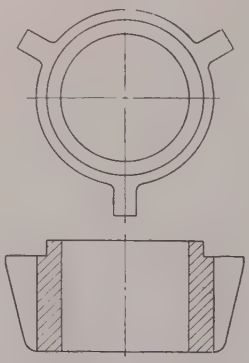


FIG. 193.—Lug in section.

The reason for violating the rules must be thoroughly understood in every case, as well as the method of making the necessary changes in representation.

117. Sectional Views.—Regular sectional views have been explained in Chap. VI. When regular sections result in complicated or misleading views, they are modified. Thus a sectional view of a symmetrical piece is drawn as in Fig. 190, which gives a better representation than a true section.

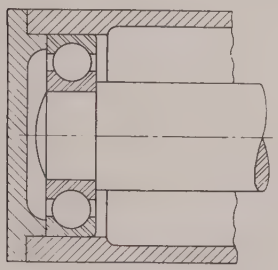


FIG. 194.—Lug in section.

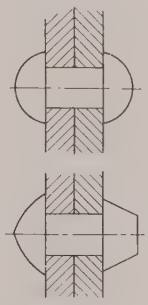


FIG. 195.—Rivets.

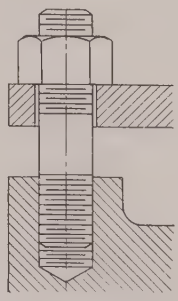


FIG. 196.—Stud.

118. Sections through Ribs, Arms, Etc.—When a section passes through a rib or pulley arm, the drawing is made as in Figs. 191 and 192, where the plane is thought of as being just in front of the rib or arm. In Fig. 193 the lugs are shown as symmetrical and are not sectioned. A true section in these figures would give the

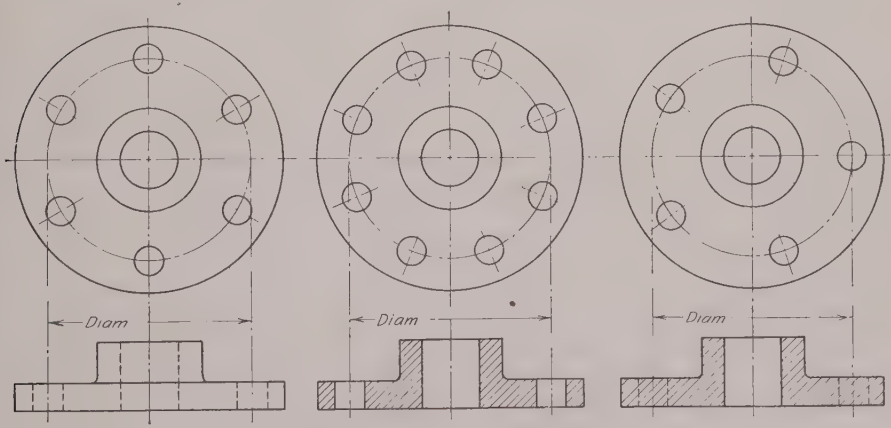


FIG. 197.—Flanges in elevation and in section.

idea of a very heavy solid piece. Shafts, rivets and bolts are represented in full as in Figs. 194, 195 and 196. When a section or elevation of a drilled flange is drawn, the holes are shown at their true distance from the center regardless of where they would project (Fig. 197).

A revolved section is sometimes inserted in a view to show the shape, as in Figs. 198 and 199.

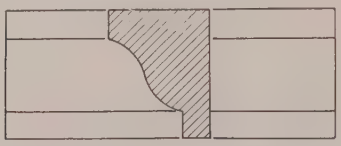


FIG. 198.—Revolved section.

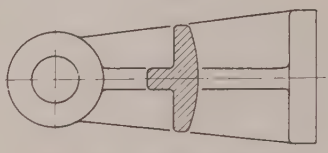


FIG. 199.—Revolved section.

119. Rule of Contour.—In general, preserve the characteristic contour of an object. Sections or elevations of symmetrical pieces are sometimes hard to read when drawn in true projection. It is usual in such cases to revolve a portion of the object until the characteristic contour shows. This has been done in Fig. 200 which illustrates applications of the rule of contour.

It is always desirable to show true distances even though the views do not project. This may be illustrated by bent levers and similar pieces which are represented by revolved or stretched-out views as in Fig. 201.

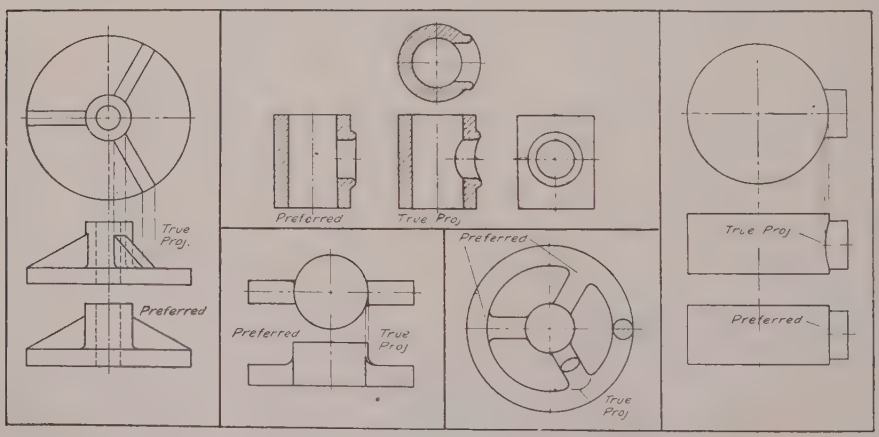


FIG. 200.—The rule of contour.

120. Rough and Finished Castings.—Castings are made by pouring melted cast iron into molds formed in sand. Wooden patterns are used to form the mold. The cooled iron as removed from the mold has rough surfaces from contact with the sand. Sometimes the casting can be used in this form, but more often some of the surfaces must be "finished" or made smooth and brought to size by machining. Round surfaces are finished on

a lathe or similar machine. Flat surfaces are finished on a shaper, planer, milling machine or similar machine.

Finished surfaces must always be indicated on a drawing, and, when necessary, the degree of accuracy must be specified

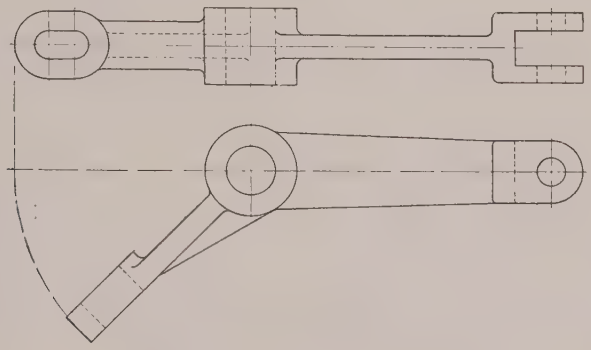


FIG. 201.—A stretched-out section.

121. Fillets and Rounds.—Sharp corners and edges are generally undesirable on unfinished machine parts with respect to strength and appearance. For this reason, interior corners are filled in with "fillets" and exterior corners are rounded.

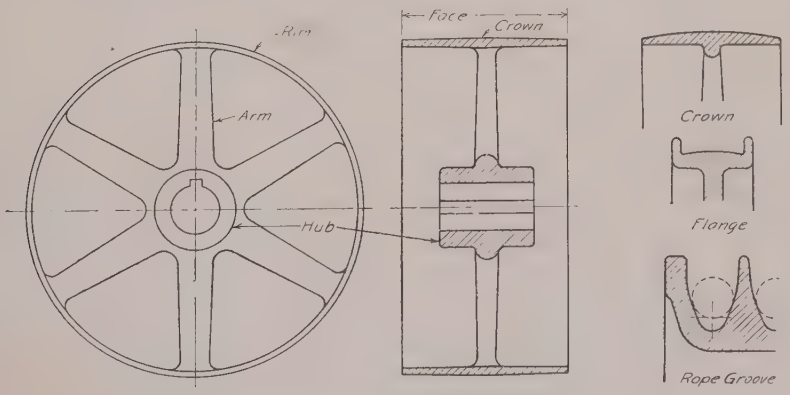


FIG. 202.—Pulleys and flanges.

122. Pulleys and Flywheels.—Included under this general head are pulleys for belt transmission, flywheels for the storing of energy and handwheels for adjustment. Each has a rim, arms and a hub.

Belt pulleys (Fig. 202) are made of cast iron, steel, wood, paper, etc. The face of a belt pulley is generally crowned (made higher in the center). The crown tends to keep the belt centered.

Sometimes flanges are used on small belt pulleys. For rope driving, grooved pulleys are used.

Flywheels have heavy rims which store up or give out energy when the speed changes. The rim of a flywheel is, therefore, thick in proportion to width in order to concentrate weight. Flywheels are made in many forms for use on steam engines, gas engines, presses and other machinery where their regulating action is needed.

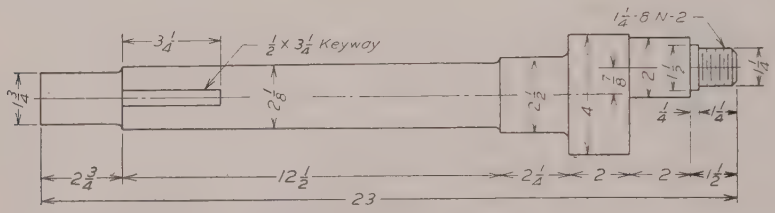


Fig. 203.—Shaft drawing.

123. Bearings.—Bearings may be either flat, as used on planer ways, or round, as used for shafts. Plain, ball or roller bearings are designed for use under varying conditions of load and speed.

Plain bearings are generally lined with Babbitt metal or some other substance that is softer than the shaft in order to reduce losses due to friction. A hole through a piece of metal is the simplest type of bearing. It may or may not be lined or bushed.

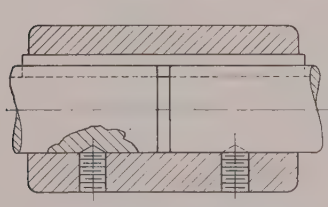


Fig. 204.—Sleeve coupling.

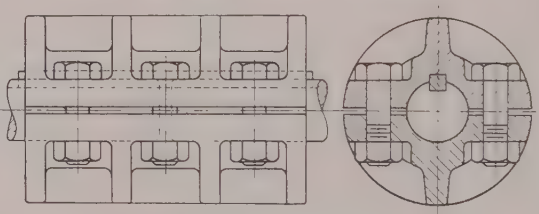


Fig. 205.—Split coupling.

124. Shafting.—Shafting drawings are of two general kinds. Transmission or line shaft drawings are made to show the location of pulleys, gears, bearings, keyways, etc. The diameter and length of the shaft must be shown, together with the locating dimensions and notes specifying the sizes and kinds of the various features. Shafting is made of either hot-rolled or cold-rolled steel.

Drawings for machine shafts are made in the same way as for other machine parts (Fig. 203). Complete information must be given by dimensions and notes. Shafts are made of steel of a grade suited to the purpose for which they are used. They are machined to size.

125. Shaft Couplings.—For joining lengths of line shafting end to end, couplings of various types are used. Two forms of sleeve couplings are illustrated in Figs. 204 and 205. A flange coupling is shown in Fig. 472, and an Oldham coupling in Fig. 509;

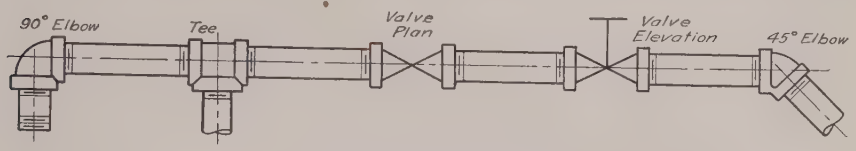


FIG. 206.—Screwed pipe fittings.

the latter is used when the shafts are parallel but may be slightly out of line with each other.

126. Pipe.—Pipe is used in conveying fluids and is made of various materials—lead, brass, wrought iron, steel, cast iron, wood, concrete, etc.

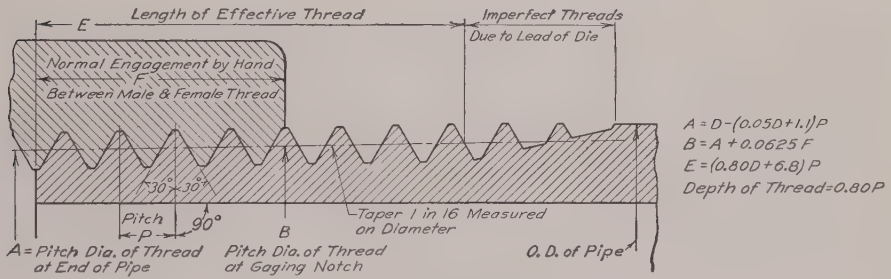


FIG. 207.—American Standard pipe thread.

For steam, gas and similar purposes, standard pipe of steel or iron is commonly used. Such pipe is specified by its nominal inside diameter, which differs from its actual diameter by small amounts as indicated in Table VIII.

FIG. 208.—Welded fittings.

For high-pressure work, extra heavy (X) pipe is made with thicker walls. The outside diameters are the same as for standard pipe. This reduces the inside diameter for the same nominal size of pipe. Double extra heavy (XX) pipe is used for still higher pressures. Large pipe, over 12″ diameter, is specified by its outside diameter and the thickness of metal. It is called "O.D. pipe."

127. Pipe Threads and Fittings.—Ordinarily pipe is "made up" or put together with "fittings." The ends of the pipe may be threaded or plain. Several forms of screwed (threaded) fittings are shown in Fig. 206. The American Standard form

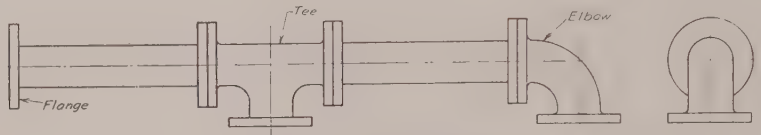


Fig. 209.—Flanged fittings.

of pipe thread (Fig. 207) is used on screwed pipe and fittings. Plain (beveled)-end pipe and fittings (Fig. 208) are welded together. Flanged fittings and pipe (Fig. 209) may be used for large sizes of pipe, or the pipe may be welded.

Table VIII.—American Standard Wrought Pipe

Nominal size	Threads per inch	Outside diameter	Actual inside diameter		
			Standard	Extra heavy	Double extra heavy
⅛	27	0.405	0.269	0.215	
¼	18	0.540	0.364	0.302	
⅜	18	0.675	0.493	0.423	
½	14	0.840	0.622	0.546	0.252
¾	14	1.050	0.824	0.742	0.434
1	11½	1.315	1.049	0.957	0.599
1¼	11½	1.660	1.380	1.278	0.896
1½	11½	1.900	1.610	1.500	1.100
2	11½	2.375	2.067	1.939	1.503
2½	8	2.875	2.469	2.323	1.771
3	8	3.500	3.068	2.900	2.300
3½	8	4.000	3.548	3.364	2.728
4	8	4.500	4.026	3.826	3.152
4½	8	5.000	4.506	4.290	3.580
5	8	5.563	5.047	4.813	4.063
6	8	6.625	6.065	5.761	4.897
7	8	7.625	7.023	6.625	5.875
8	8	8.625	8.071	7.625	6.875
8	8	8.625	7.981		
9	8	9.625	8.941	8.625	
10	8	10.750	10.192	9.750	
10	8	10.750	10.136		
10	8	10.750	10.020		
11	8	11.750	11.000	10.750	
12	8	12.750	12.090	11.750	
12	8	12.750	12.000		

128. Sizes of fittings are specified by the "nominal" size of pipe with which they are used. Reducing fittings are used to join different sizes of pipe. The size is specified by giving the largest

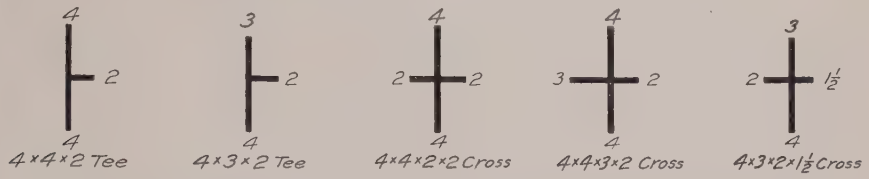


Fig. 210.—Sizes of pipe fittings.

"run" opening first, then the opposite end of the run. For tees and crosses the side outlets are given last (Fig. 210).

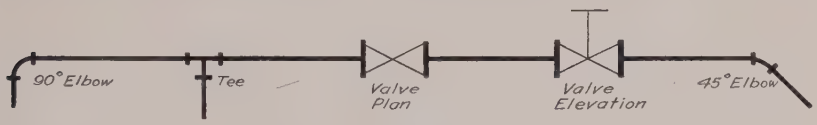


Fig. 211.—Single-line conventions.

129. Piping Drawings.—Drawings for piping layouts are made as illustrated in Fig. 206, with dimensions and notes added to specify sizes, kinds and location. For small-scale drawings and

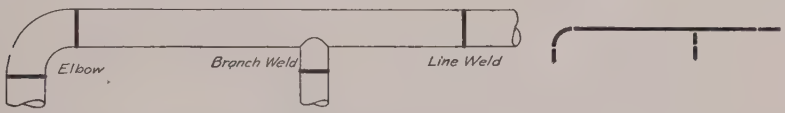


Fig. 212.—Welded-pipe representations.

sketches the single-line conventions of Fig. 211 are used. Welded piping may be shown as in Fig. 212. Pictorial methods of representation are often convenient.

CHAPTER XII

GEARS AND CAMS

130. Gears and cams are machine elements which frequently occur on working drawings. The theory and specification of

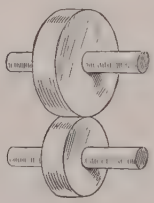


FIG. 213.—Friction wheels.

gears and cams are important divisions of the study of mechanism to which the student is referred. The student should, however, know how to represent gears and cams on drawings as indicated in this chapter.

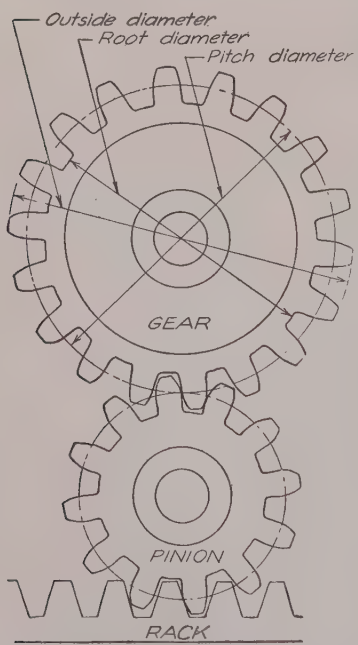


FIG. 214.—Spur gears and rack.

131. Gears.—If two wheels are in contact and are keyed to parallel shafts, both will revolve if either one of the shafts is turned (Fig. 213). If the driven shaft turns hard, the wheel will slip. To prevent slipping, teeth are added to the wheels. The shape of these teeth is such that the same kind of motion is obtained as with the rolling wheels. Spur gears and bevel gears (Figs. 214 and 215) are the most common forms.

A small gear used with a large one, or with a "rack," is called a "pinion." The parts of gear teeth have names, as given in Fig. 216. There are three diameters and two kinds of pitch to remember. The three diameters are indicated on the figure. The

circular pitch is the distance from a point on one tooth to the same point on the next tooth measured along the pitch circle. The diametral pitch is a number found by dividing the number of teeth

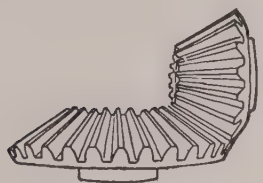


FIG. 215.—Bevel gears.

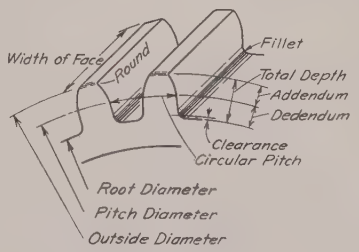


FIG. 216.—Gear terms.

by the diameter of the pitch circle. Gear drawings are illustrated in Figs. 217, 218 and 219. It is not necessary to draw the actual teeth when making working drawings of gears. Cut spur and bevel gears are drawn as in Figs. 217 and 218. These drawings

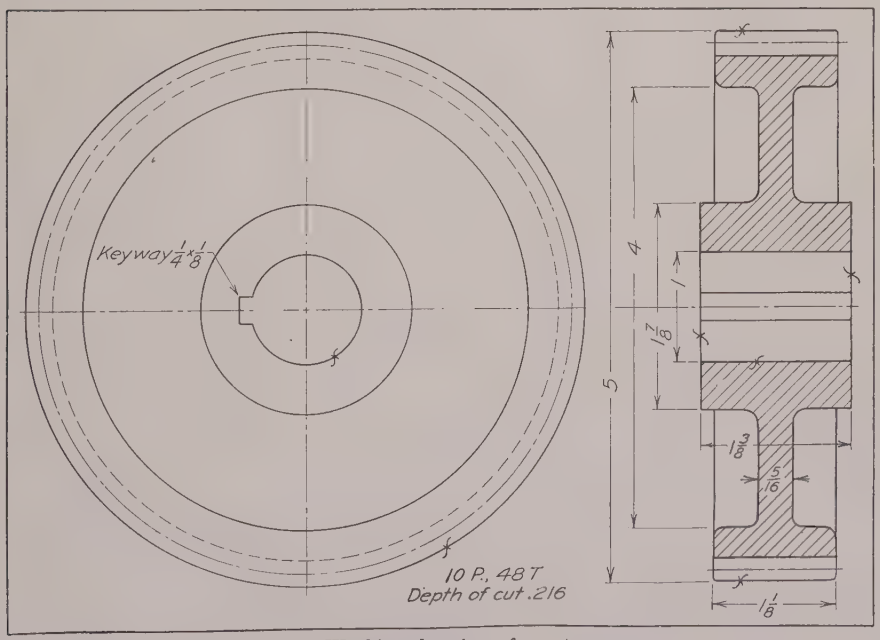


FIG. 217.—Working drawing of a cut spur gear.

show "gear blanks" with dimensions for making the patterns and machining and notes to give the required information for cutting the teeth.

On assembly drawings it is usual to give the number of teeth and the pitch with representations as in Fig. 219.

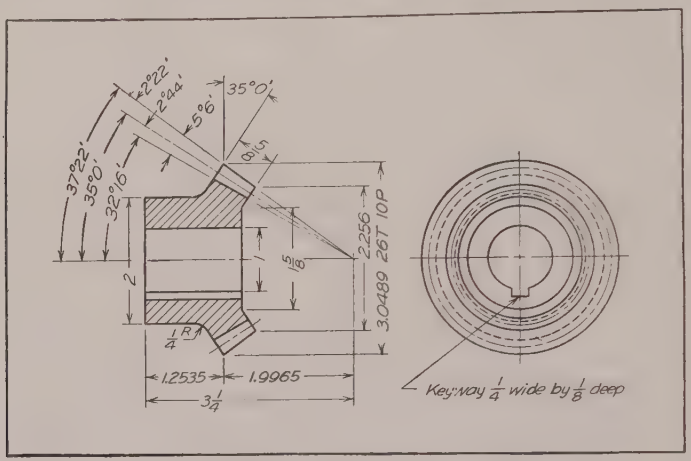


Fig. 218.—Working drawing of a cut bevel gear.

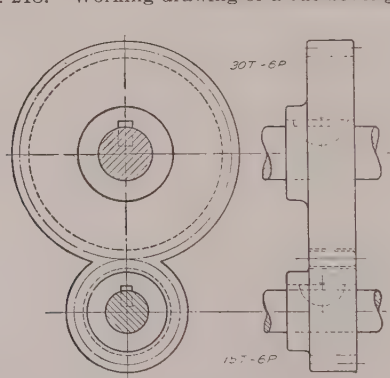


Fig. 219.—Gears in elevation.

132. Gear Terms and Abbreviations.—The following information and formulas can be used to find required dimensions, etc., for standard gears:

N = number of teeth

A = addendum = $\dfrac{1}{DP}$

D = dedendum = $\dfrac{1.157}{DP}$

C = clearance = $\dfrac{0.157}{DP}$

PD = pitch diameter = $\dfrac{N}{DP}$

OD = outside diameter = $\dfrac{N+2}{DP}$ = $2A + PD$

CP = circular pitch = $\dfrac{\pi PD}{N}$

DP = diametral pitch = $\dfrac{N}{PD}$

RD = root diameter = $PD - 2D$

WD = whole depth = $A + D$

133. Cams.—A cam is a machine element used to obtain an irregular or special motion not easily obtained by other means. The shape of a cam is derived from the motion required of it. A plate cam and a cylindrical cam are shown in Figs. 220 and 221. Some cam terms are shown on Fig. 222.

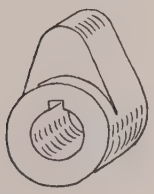


FIG. 220.—Plate cam.

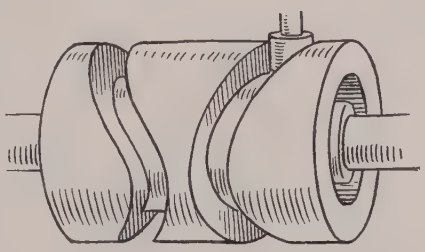


FIG. 221.—Cylindrical cam.

134. To find the cam outline (Fig. 223), given point C, the center of the shaft, and point A, the lowest position of the center of the roller: It is required to raise the center of the roller with uniform motion during three-eighths of a revolution of the uni-

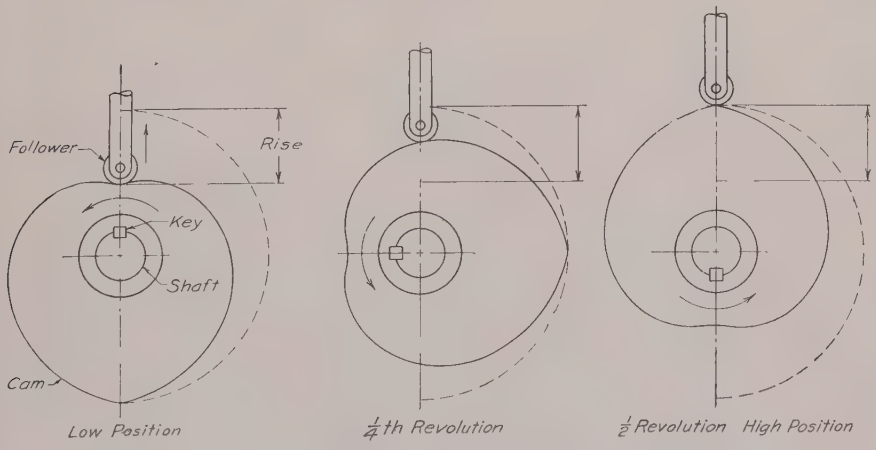


FIG. 222.—Cam action.

formly revolving shaft, to allow it to drop two-thirds of the way down instantly, to remain at rest for one-eighth of a revolution, to drop uniformly during three-eighths of a revolution and to remain at rest for the remaining one-eighth of a revolution.

Divide the rise into a number of equal parts. Divide the arc ADE into the same number of equal spaces as there are spaces in

the rise, and draw radial lines. With C as a center and radius $C1$, draw an arc intersecting the first radial line at $1'$. In the same way locate points $2'$, $3'$, etc., and draw a smooth curve through them. If the cam is revolved in the direction of the arrow, it will raise the roller with the desired motion. Draw $B'J$ equal to two-thirds of AB. Draw arc JK with radius CJ. Divide $A2$ into

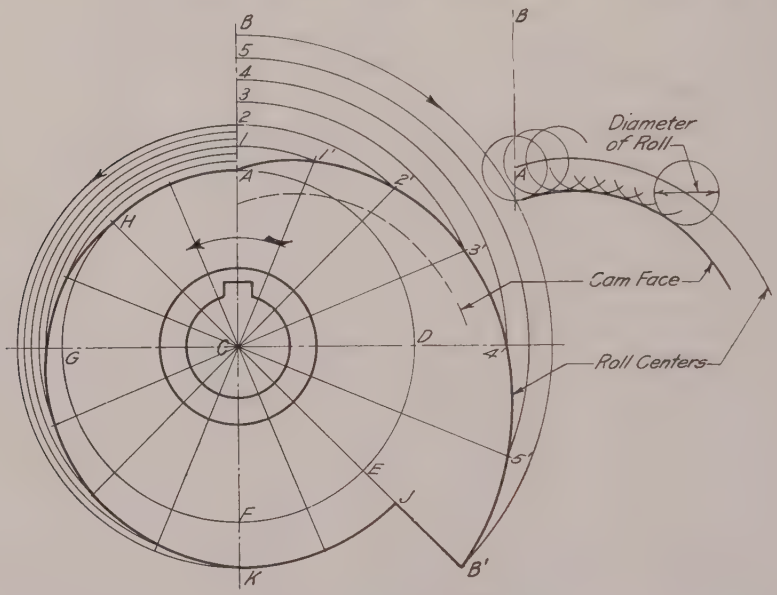


Fig. 223.—Drawing a plate cam.

six equal parts and arc FGH into six equal parts. Circle arc, when drawn as shown, will locate points on the cam outline. Draw arc HA with radius CH to complete the cam. This outline is for the center of the roller, allowance for which may be made by drawing the roller in its successive positions and then drawing the tangent curve as shown in the auxiliary figure.

CHAPTER XIII

PICTORIAL DRAWING

135. In working drawings the shape description is always done by the exact method of separate views, or orthographic projection, as studied in the previous chapters. But in addition to a knowledge of this system of drawing, a draftsman should be able to make a pictorial view either freehand or with instruments. The ability to make a pictorial sketch or drawing quickly and effectively will be found to be of great value in preliminary designing, in aiding in the reading and visualization of a drawing, in showing the appearance of an object to persons not able to read orthographic projection and in illustrating notes,

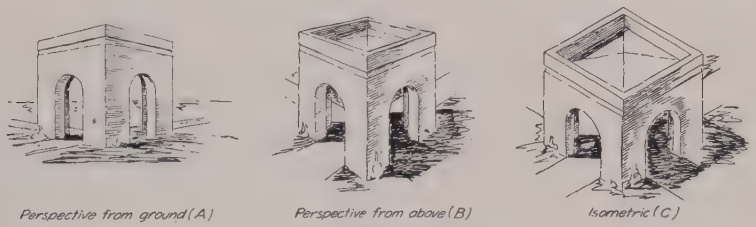


FIG. 224.—Pictorial drawing.

reports and published articles. In studying drawing, one of the best exercises is to translate orthographic drawings into pictorial drawings.

By those familiar with the subject, sketches are often made in *perspective*, showing the object as it would actually appear to the eye as at *A* and *B* in Fig. 224. An easier way, although the result is not so pleasing in appearance as a well-made perspective, is to use one of the pictorial methods of projection, such as isometric drawing, Fig. 224 at *C*. Other common methods in addition to *isometric drawing*, include *oblique drawing* and *cabinet drawing*. These all show three faces in one view and have the advantage that the principal lines can be measured directly. Although similar in effect, these three methods must not be confused.

136. Isometric Drawing.—This simple method is based on revolution as illustrated in Fig. 225, which shows three views of a cube in the usual position at (1); three views when the cube has been revolved about a vertical axis, so that two faces show as equal rectangles in the front view at (2); and three views when the cube has been revolved forward (tilted up on one corner) through such an angle that the front view shows three faces equal in shape and size at (3). This front view is called an *isometric*[1] projection.

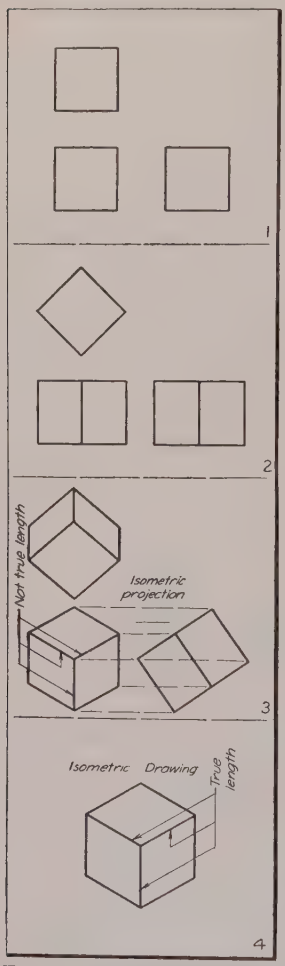


FIG. 225.—The isometric cube.

In this position the edges would evidently not show in their true length. An *isometric drawing* of the same cube is the same shape, Fig. 225 at (4), but a little larger in size as the edges are drawn in their true length instead of in the foreshortened length. This variation in size does not affect the pictorial value of the view for shape description but it does simplify the drawing of the view as all measurements can be made with the regular scale. This makes it possible to draw the desired pictorial view at once without projecting from other views or using a special scale.

Isometric drawings are thus built on a skeleton of three lines representing the three edges of the cube. These three lines form three equal angles of 120° and are called the "isometric axes." One is drawn vertically, the others with the 30° triangle as shown in Fig. 226. The intersection of these lines would be the front corner of a block with square corners. Measuring the length, breadth and thickness of the block on the three axes and drawing through these points lines parallel to the axes will give the isometric drawing of the block. It is often better to start with the axes in the "second position," representing the lower corner as in Fig. 227.

[1] Isometric—equal measure.

Any line on the object parallel to one of these edges is drawn parallel to it and is called an *isometric line.* The first rule of isometric drawing is: *Measurements can be made only on isometric lines.* The second rule is: *Remember the isometric cube.*

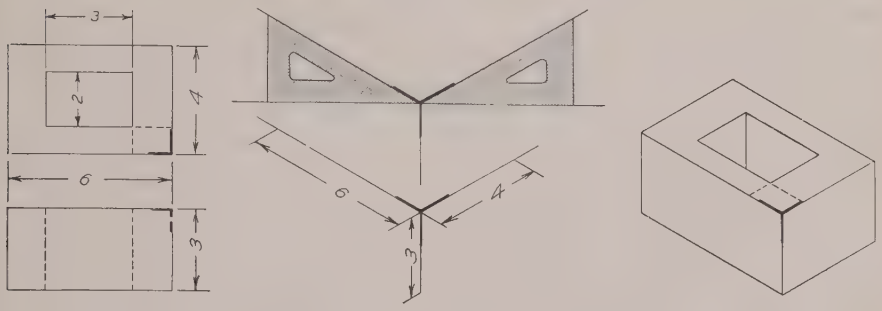


Fig. 226.—Isometric axes. First position.

137. Non-isometric Lines.—Lines not parallel to one of the isometric axes are called *non-isometric* lines. Such lines will not show in their true length and cannot be measured but must be drawn by locating their two ends.

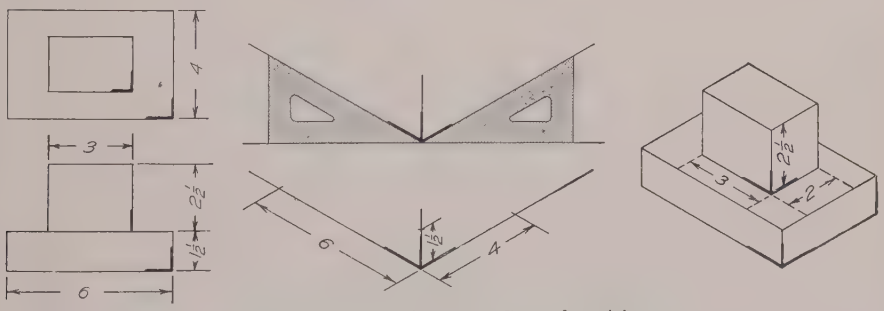


Fig. 227.—Isometric axes. Second position.

Angles between lines on isometric drawings do not show in their true size and cannot be measured in degrees. All the angles of a cube are right angles, but in the isometric drawing some would measure 120° and some 60°. In drawing angles other than 90°, the lines forming them must be transferred from the orthographic views as shown in Fig. 228. To make an isometric drawing of the packing block shown at I, first drop perpendiculars on the front view from the points *D* and *E*, giving the construction lines *DF* and *EG*. Then draw the two isometric axes, *AB* and *AC*, as at II, and measure the distances *AF* and *BG*. Draw vertical lines at *F* and *G* equal to the corresponding lines in the front view. The

non-isometric lines AD and BE can then be drawn, and the angles at A and B will be represented correctly. Finish the figure as at III.

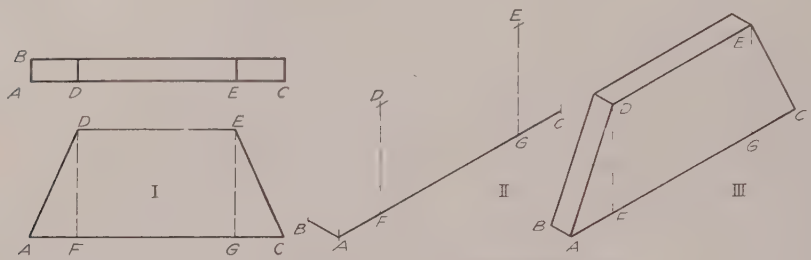


Fig. 228.—Construction for non-isometric lines.

138. Circles will appear as ellipses in isometric drawing, but instead of drawing a true ellipse, a four-centered approximation

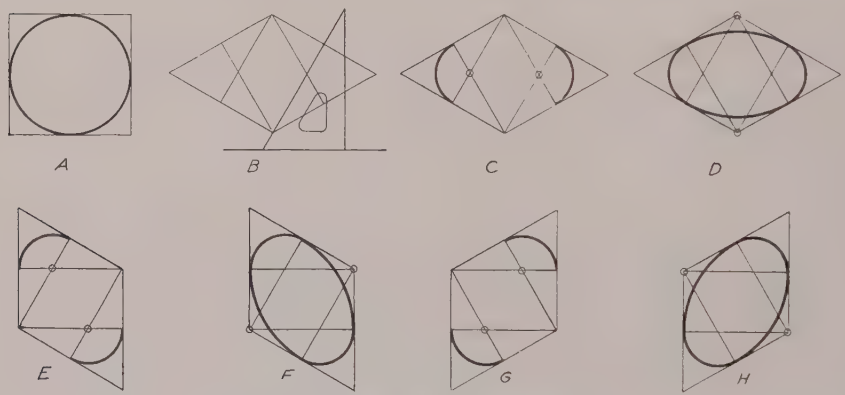


Fig. 229.—Construction for isometric circle.

is usually made. To draw an isometric circle, first make the isometric drawing of the square which will contain it (Fig. 229 at A). From the points of tangency, draw perpendiculars, as

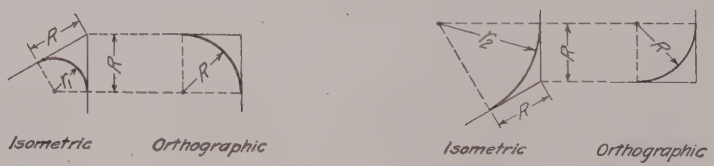


Fig. 230.—Isometric arcs.

indicated at B. Their intersections will give four centers from which arcs may be drawn tangent to the sides of the isometric square. Two of these centers will fall on the intersections of

the perpendiculars, as shown at C, and two at the corners as shown at D. Thus the entire construction may be made with the 60° triangle. Circles on the left or right surfaces of the object may be drawn in the same way, as shown at E, F, G, H in Fig. 229.

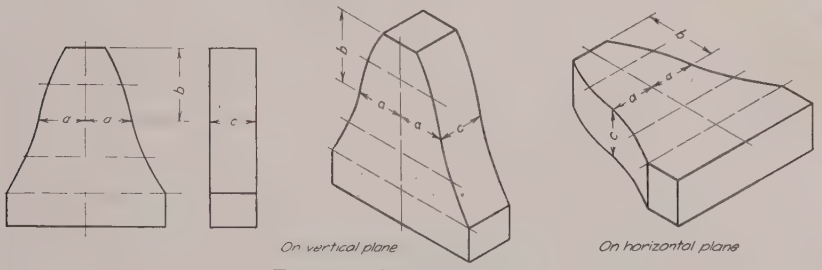


FIG. 231.—Isometric curves.

The construction for quarter rounds is the same, as shown in Fig. 230, where the radius is measured from the corner and actual perpendiculars of 90° drawn to find the required center.

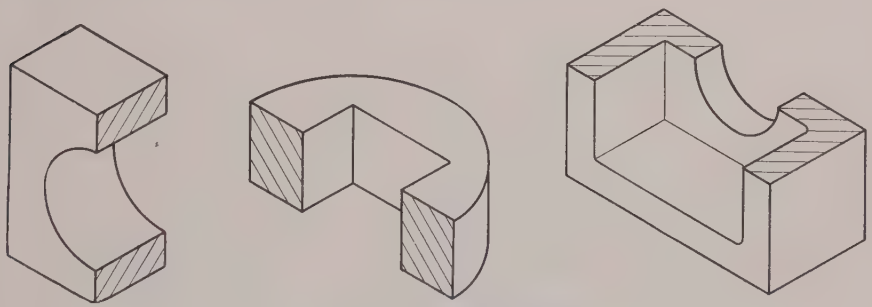


FIG. 232.—Isometric sections.

139. Isometric Curves.—Curves other than circle arcs are drawn by plotting a series of points. This is illustrated in Fig. 231. First draw the orthographic view and locate a number of points by drawing lines as shown. Draw these same lines in isometric as illustrated for a vertical plane and a horizontal plane. Then plot points by transferring distances from the orthographic to the isometric view and draw a smooth curve through the points.

140. Sections.—Isometric drawings are generally made as outside views, but sometimes a sectional view is needed. The section is taken on an "isometric plane," that is, on a plane parallel to one of the faces of the cube. Figure 232 shows isometric full sections, and Fig. 233 shows isometric half sections. Notice the

construction lines, in Fig. 233 at *B*, which were used to draw the view shown at *C*.

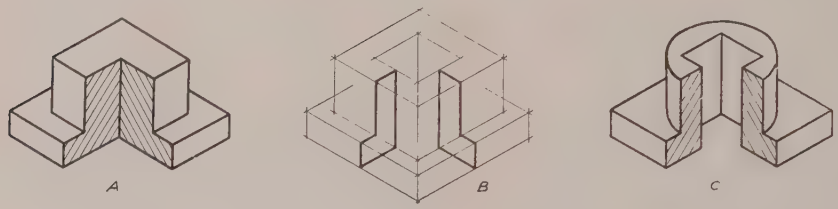


Fig. 233.—Isometric half-sections.

141. Making an Isometric Drawing.—Problem: Make an isometric drawing of the guide of Fig. 234. First, draw the axes *AB*, *AC* and *AD*, in second position (Fig. 235).

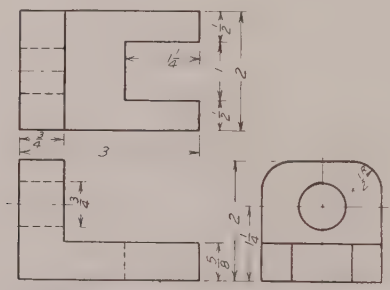


Fig. 234.—Problem for isometric drawings.

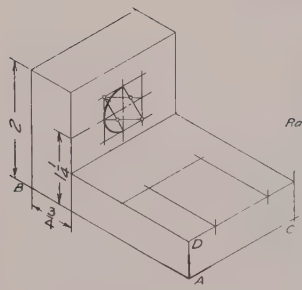


Fig. 235.—First stage.

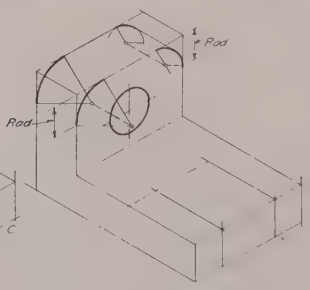


Fig. 236.—Second stage.

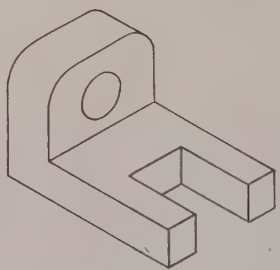


Fig. 237.—Completed.

Measure from *A*, the length 3″ on *AB*.
Measure from *A*, the width 2″ on *AC*.
Measure from *A*, the thickness $\frac{5}{8}$″ on *AD*.

Through these points draw isometric lines, blocking in the base. Second, block in the upright, making two measurements only, 2″ and $\frac{3}{4}$″. Third, locate center of hole, and draw its center lines

as shown. Block in a $\frac{3}{4}''$ isometric square and draw the hole as an approximate ellipse by Art 138. At the upper corners measure the one-half inch radius on each line (Fig. 236), and draw real perpendiculars to find the centers of the quarter circles. Fourth, finish the drawing as in Fig. 237.

142. Making a Freehand Isometric Drawing.—Freehand isometric sketches are of great help in reading orthographic views and in explaining objects or parts of construction. The principles of isometric drawing form the basis of isometric sketching, but, since sketches are not made to scale, their appearance is improved by flattening, that is, giving the axes an angle less than 30° with the horizontal, and by slightly converging the lines, as well as foreshortening the lengths, thus avoiding the distortion and giving the effect of perspective. This is sometimes called "fake perspective."

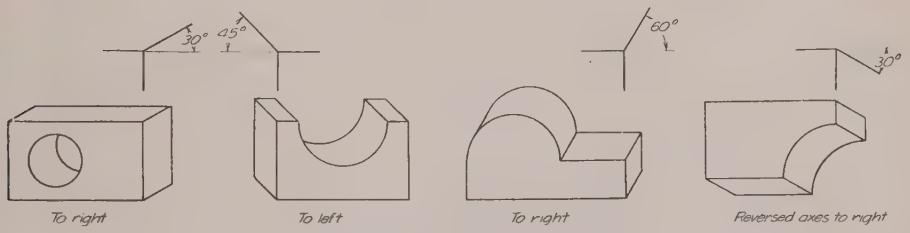


FIG. 238.—Axes in oblique drawing.

Always block in construction squares before sketching circles or arcs, and remember that the long axes of ellipses representing circles on the top face are horizontal.

Dimensioning a pictorial sketch is illustrated in Fig. 138, Art. 73.

143. Oblique Drawing.—This form of pictorial drawing is based upon the theoretical principle that the object is placed parallel to the plane of projection and projected to it by oblique projecting lines instead of perpendicular ones. Practically, it is drawn on three axes, just as in isometric drawing, but two of the axes always make right angles with each other; that is, one axis is drawn vertically, one horizontally and the third at any convenient angle (Fig. 238).

The same methods and rules as used in isometric apply to oblique, but compared with isometric, it has the distinct advantage of showing one face without distortion. Thus objects with irregular outlines can be drawn by this method much more easily and

effectively than in isometric, and many draftsmen prefer it for practically all pictorial work.

The first rule in oblique drawing is: *Place the object so that the irregular outline or contour faces the front.*

If there is no irregular outline, the second rule should be followed: *Always place the object so that the longest dimension shows in the front.*

144. Circles.—On the front face, circles and curves show in their true shape. On the other faces, they are drawn as in isometric, by drawing perpendicular lines from the tangent points.

145. Making an Oblique Drawing.—Problem: Make an oblique drawing of the bearing of Fig. 239. First, draw the axes for the base, *AB*, *AC* and *AD*, in second position, and measure on them the length, width and thickness of the base (Fig. 240). Draw the base, and on it block in the upright, omitting the projecting boss, as shown in the figure. Second, block in the boss, as in Fig. 241, and find the centers of all circles and arcs. Third, draw the circles and circle arcs. Fourth, finish the drawing as in Fig. 242.

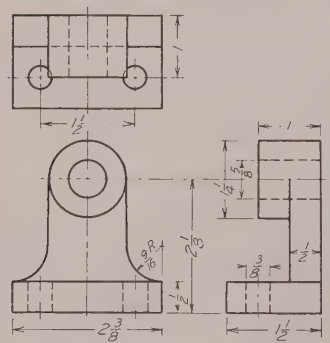


Fig. 239.—Problem for oblique drawing.

146. Cabinet Drawing.—In this form of drawing the axes are taken the same as in oblique drawing, but all measurements parallel to the oblique or cross axis or, in other words, all thickness measure-

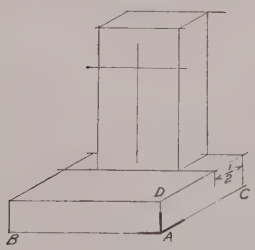


Fig. 240.—First stage.

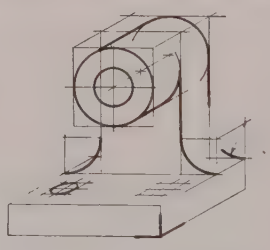


Fig. 241.—Second stage.

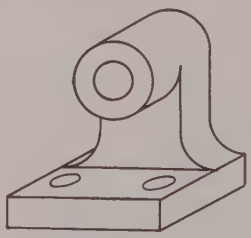


Fig. 242.—Completed.

ments from front to back, are reduced one-half. It is used sometimes in making drawings of wood construction.

147. Perspective Drawing.—Perspective drawing is the representation of an object as it actually appears to the eye. A sketch made in perspective thus gives the best pictorial effect. The elementary principles of perspective are familiar to most students

through the study of freehand drawing, and they will find this knowledge of value in studying shape description.[1]

In the perspective sketch (Fig. 243) it will be noted that the vertical lines remain vertical and that the two sets of horizontal lines each converge toward a point called the "vanishing point."

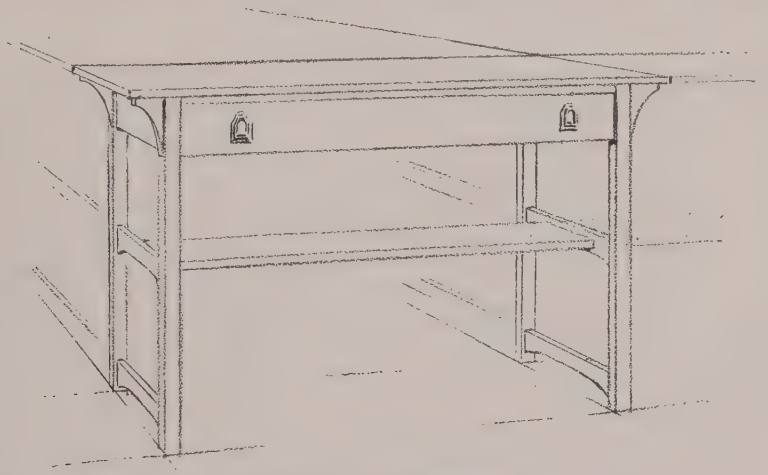


FIG. 243.—Angular perspective.

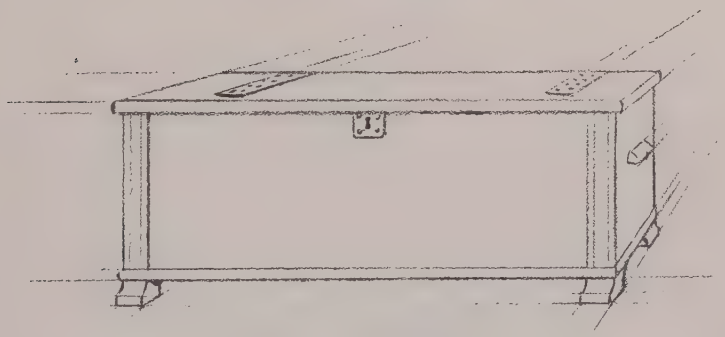


FIG. 244.—Parallel perspective.

These two vanishing points lie on a horizontal line at the level of the eye called the "horizon." The first rule is: *All horizontal lines vanish on the horizon.*

When the subject is turned at an angle, as in Fig. 243, the drawing is said to be in angular or "two-point" perspective.

[1] In the scope of this book the interesting subject of mechanical perspective construction cannot be taken up. With a knowledge of its methods, perspective drawings can be made from working drawings, as, for example, when an architect makes a picture of a proposed building, the result being as accurate as a photograph of the building (Fig. 308).

If the object is turned so that one face is parallel to the front plane, the horizontal lines on that face, or parallel to it, remain horizontal and have no vanishing point. This drawing is called "parallel," or "one-point," perspective (Fig. 244).

148. Making a Perspective Sketch.—In sketching from the object, place it below the level of the eye (unless very large) and so as to show the outline of shape to the best advantage. Start by drawing a line for the nearest vertical corner. From this, sketch lightly the directions of the principal lines, running them past the limits of the figure. Test the directions and proportionate lengths with the pencil as follows: With the drawing board or sketch pad held *perpendicular* to the "line of sight" from the eye

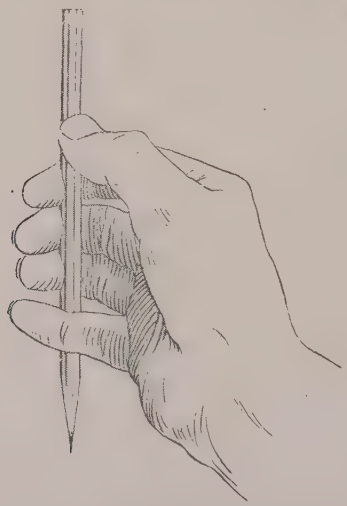


Fig. 245.—Estimating proportions.

to the object, hold the pencil at arm's length *parallel* to the board and rotate the arm until the pencil appears to coincide with the line on the model, then move it parallel to this position back to the board. This gives the direction of the line. To estimate the apparent lengths, hold the pencil the same way and mark with the thumb (Fig. 245) the length of the pencil which covers the line. Rotate the arm with the thumb held in position until the pencil coincides with another line, and estimate the proportion of this measurement to the second line.

Block in the enclosing squares for all circles and circle arcs. Work with light free sketchy lines, and do not erase any lines until the whole sketch is blocked in. Draw main outlines first, then add details. Finally, brighten the sketch with heavier lines.

CHAPTER XIV

GRAPHIC SOLUTIONS

149. The drawing studied in the previous chapters has had as its main purpose the methods of describing the shape and size of constructions so that they could be built from the drawings. Another important use of drawing is in the graphical solution of problems. For both of these uses a draftsman should be familiar with geometrical constructions.

150. Lines.—A line may be divided into two equal parts by measurement with the scale, by trial with the dividers, as described in Art. 15, or geometrically, as in Fig. 246. Given the line AB: With a radius greater than one-half AB, draw arcs with A and B

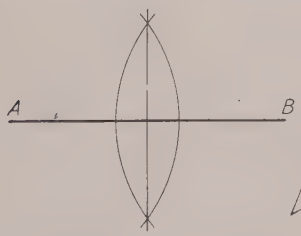


Fig. 246.—To bisect a line.

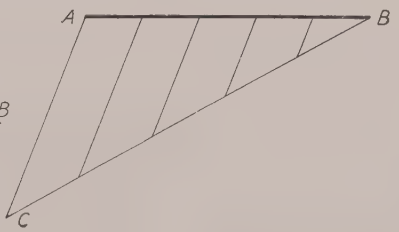


Fig. 247.—To divide a line.

as centers. A line drawn through the intersections of the arcs will be perpendicular to AB and will divide it into two equal parts or bisect it.

151. A line may be divided into any number of equal parts by trial with the dividers, as described in Art. 15, or by using the scale as described in Art. 16. Another way is by the geometrical method of Fig. 247. To divide the line AB into *five* equal parts: from B draw another line at any angle. On it step off *five* equal spaces of any convenient length. Connect the last point (C) with A. Through the other points draw lines parallel to CA, using triangle and T-square as shown in Fig. 11.

152. Sometimes it is necessary to reduce or enlarge linear dimensions from one size to another. A special scale for this purpose may be made geometrically on the well-known theorems of

proportional triangles. Draw two parallel lines at a convenient distance apart, one, AB, to the given scale and the other, CD, to the desired length, either shorter (Fig. 248) or longer (Fig. 249). Lines through AC and BD will intersect at point O. Draw lines from point O through each division of the given scale AB. These

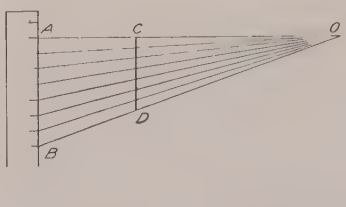


Fig. 248.—Reducing.

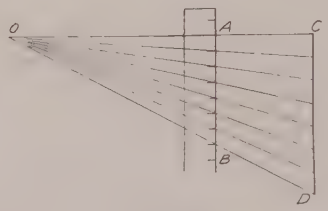


Fig. 249.—Enlarging.

will divide CD into proportional spaces, thus making a new scale from which the desired measurements can be taken.

153. Angles.—The size of the angle between two lines is measured in degrees. As there are 360° in a circle, a right angle would contain 90°. For measuring and laying out angles, an instrument called a "protractor" is used. The usual form is semi-circular, as shown in Fig. 250.

In Art. 8 (Fig. 10) we learned that angles varying by 15° could be constructed with the 30°–60° and 45° triangles. An angle of 90° may be readily bisected with the 45° triangle or trisected with the 30°–60° triangle.

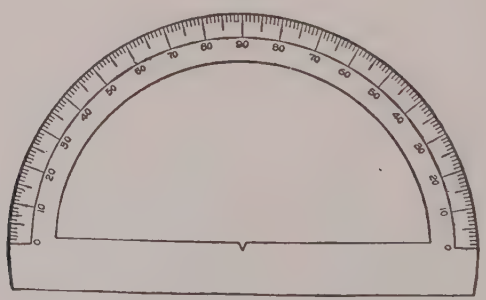


Fig. 250.—A protractor.

154. To Bisect an Angle (Fig. 251).—With O as a center and any radius, draw an arc cutting the sides at A and B. With A and B as centers and any radius greater than one-half AB, draw intersecting arcs. A line through this intersection and the point O will bisect the angle.

155. To Copy an Angle (Fig. 252).—Given the angle AOB and line $O'B'$: Draw an arc with O as a center and any convenient radius. With O' as a center and the same radius, draw another arc. With radius equal to the chord CD, draw an arc with C' as center intersecting the first arc at D'. Then the angle $D'O'C'$ will be equal to angle AOB.

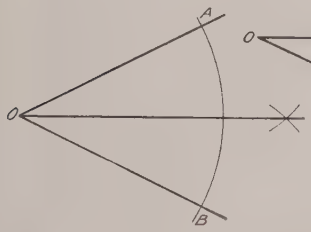


FIG. 251.—To bisect an angle.

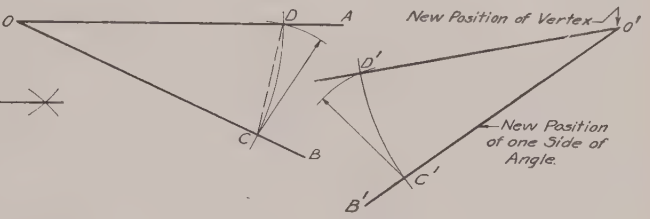


FIG. 252.—To copy or transfer an angle.

156. Triangles.—To construct a triangle, having given the lengths A, B and C of the three sides (Fig. 253): Draw one side, as A, in the desired position. With its ends as centers and radii B and C, draw two intersecting arcs as shown.

An *equilateral* triangle has three equal sides. It may be constructed by drawing one side in the desired position and drawing intersecting arcs with the ends as centers and the length of the side as a radius, or by drawing 60° lines from each end of the base, using the 30°–60° triangle (Fig. 254).

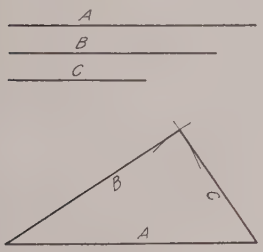


FIG. 253.—To construct a triangle.

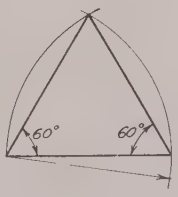


FIG. 254.—Equilateral triangle.

FIG. 255.—Isosceles triangle.

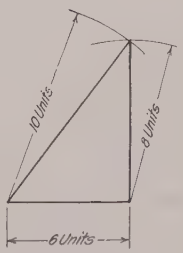


FIG. 256.—Right triangle.

An *isosceles* triangle has two equal sides (Fig. 255). It may be constructed by locating the base and drawing intersecting arcs from each end, using one of the equal sides as a radius.

A *right* triangle is one with a right angle. It may be constructed geometrically by the "6-8-10 method" when T-square and triangle cannot be used. Draw the base 6 units long. From

one end draw an arc with a radius 10 units long and from the other an arc with a radius 8 units long. Connect their intersections with the ends of the base (Fig. 256).

157. The Pentagon.—To draw a pentagon in a circle (Fig. 257): Draw a diameter AB and a radius OC perpendicular to it. Bisect OB, and with this point D as a center and a radius DC, draw the arc CE. With C as a center and a radius CE, draw the arc EF.

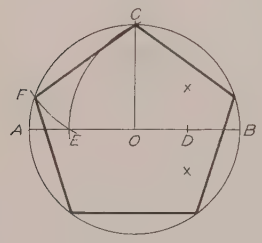


Fig. 257.— Pentagon.

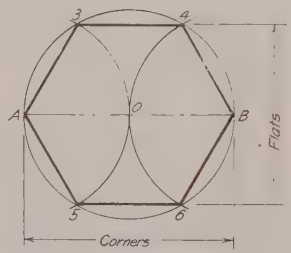


Fig. 258.—Hexagon.

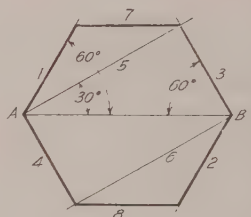


Fig. 259.—Hexagon.

Then CF will be one side of the pentagon. With the same radius mark off the remaining three points.

158. The Hexagon.—The regular hexagon can be drawn in a number of ways and has already been explained in Art. 95. If the distance across corners AB (Fig. 258) is given, draw a circle with AB as a diameter. With A and B as centers and the same radius,

Fig. 260.—Octagon.

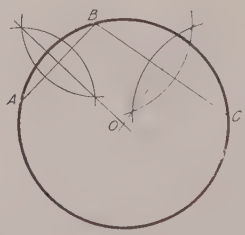


Fig. 261.—Circle.

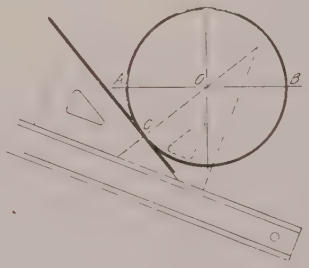


Fig. 262.—To draw a tangent.

draw arcs and connect the points. A hexagon may be constructed directly on the line AB, without using the compasses, by drawing lines with the 30°–60° triangle in the order shown in Fig. 259.

159. The Octagon.—To draw an octagon in a given square (Fig. 260): Draw the diagonals of the square. With the corners as centers and a radius of half a diagonal, draw arcs cutting the sides of the square and connect these points.

160. Arcs and Tangents.—A circle may be drawn through any three points not in a straight line. Given the points A, B and C (Fig. 261): Draw lines AB and BC. Using the method of Art. 150, bisect these lines. The point O, where the bisectors cross, will be the center of the required circle.

161. To draw a tangent to a circle, at a given point, draftsman's method (Fig. 262): Arrange a triangle in combination with the T-square (or another triangle) so that its hypotenuse passes through center O and point C. Holding the T-square firmly in place, turn the triangle about its square corner, move it until the hypotenuse passes through C and draw the tangent.

162. To Draw an Arc Tangent to Two Lines (Figs. 263 and 264).—Given two lines AB and CD and radius R: Draw lines parallel to AB and CD at a distance R from them. The intersection of these lines will be the center of the required arc. Locate

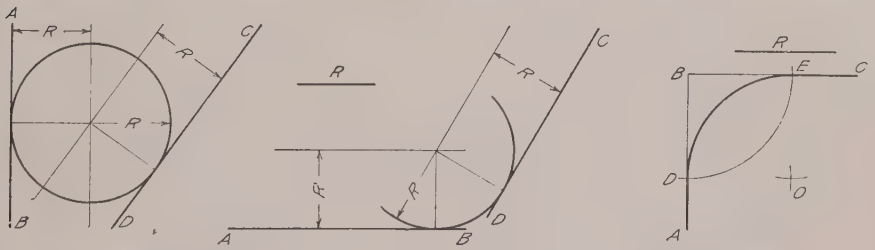


Fig. 263. Fig. 264. Fig. 265.

Fig. 263–265.—To draw an arc tangent to two lines.

the points of tangency (the stopping points for the curve) by drawing lines through the center of the arc perpendicular to the tangent lines, reversing the method of Fig. 262.

163. To Draw an Arc in a Right Angle (Fig. 265).—This is often used in drawing fillets and rounds. It is desired to round the corner ABC with an arc of radius R. With B as a center and radius R, cut the two lines at points D and E. With these points as centers and radius R, draw arcs intersecting at O. An arc with center O and radius R will be tangent to the straight lines at points D and E.

164. To draw a non-circular curve approximately with circle arcs: Find by trial the center for an arc that will cover a portion of the curve required. Connect the end of the arc with the center. The next center for an arc tangent to the first *must* lie somewhere on this line. Continue the process as in Fig. 266. Remember that when two arcs are tangent to each other, the two centers and the point of tangency *must* lie in a straight line.

165. To Lay Off on a Straight Line the Approximate Length of a Circle Arc (Fig. 267).—Given the arc AB: At A draw the tangent AD. Set the dividers to a small space. Starting at B, step along the arc to the point nearest A, and without lifting the dividers, step off the same number of spaces on the tangent, as shown.

166. To Draw a Reverse or Ogee Curve (Fig. 268).—To connect two parallel lines AB and CD by a smooth curve: Connect B and C by a straight line, and select on it a point E through which the curve is desired to pass. Bisect BE and CE (Art. 150), and extend the bisectors to meet perpendiculars drawn from B and C, giving centers for the required arcs. *Proof:* Any arc to pass through B and E must have its center on a perpendicular bisecting the line BE. Any arc tangent to AB at B must have its center on

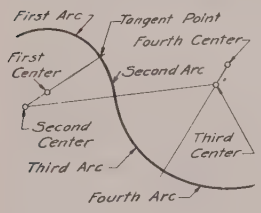


FIG. 266.—To draw tangent arcs.

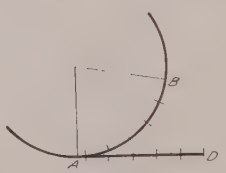


FIG. 267.—Length of an arc.

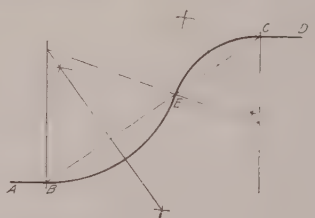


FIG. 268.—An ogee curve.

a perpendicular to AB from B. Therefore the center of an arc tangent to AB and containing E must lie at the intersection of these perpendiculars. Check by drawing line of centers, which must pass through E.

167. To Draw an Involute.—Assume a string to have been wound around the square in Fig. 269 in a counterclockwise direction and that the loose end is at point 4. Start unwinding in a clockwise direction, and the end will describe an involute. To draw the involute, take a radius 4-1 with center at 1, and draw the arc 4-1′ ending at 1′ on the side 2-1 produced. With radius 2-1′ and center 2, draw arc 1′-2′. Continue in like manner with the corners of the square as centers, increasing each successive radius by the length of a side. In the same way the involute of any polygon may be drawn.

To draw the involute of a circle (Fig. 270), divide the circumference of the circle into a number of equal parts, draw radial lines and tangents at the end of each radial line. Lay off the length of the arc from point 1 to point 2 on the tangent 2-1′ (Art. 165).

Lay off on each tangent the length of the arc from the point of tangency to point 1. Through the points thus found (1′-2′-3′, etc.), draw the involute as a smooth curve. This is the curve of the involute gear tooth.

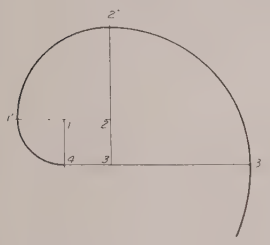


Fig. 269.—Involute.

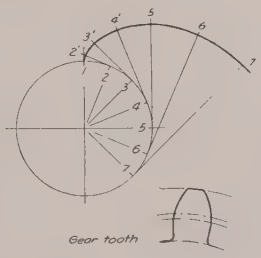


Fig. 270.—Involute of circle.

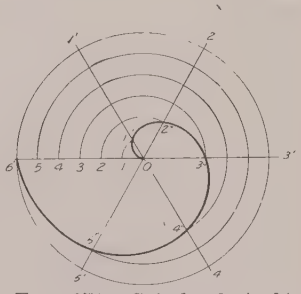


Fig. 271.—Spiral of Archimedes.

168. To Draw a Spiral of Archimedes (Fig. 271).—Draw a circle, divide it into a number of equal parts, and divide a radial line into the same number of equal parts. With *O* as a center and radius *O*-1, draw an arc to radial line *O*-1′ to locate point 1″. In like manner, draw arcs with radii 0-2, 0-3, etc., to radii to locate points 2″, 3″, etc., as shown. Draw the spiral of Archimedes through the points thus located.

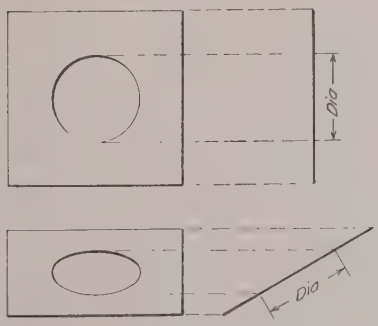


Fig. 272.—Circle projected as an ellipse.

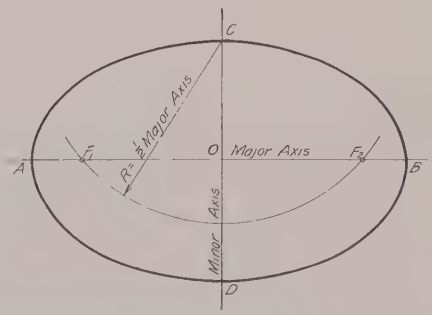


Fig. 273.—Ellipse.

169. The Ellipse.—If a circle is parallel to a plane, its projection on that plane will be a circle. If it is perpendicular to the plane, its projection will be a straight line. If it is at an angle, its projection will be an ellipse. A square card with a circular hole, drawn in different positions, as in Fig. 272, illustrates the foregoing statements. An ellipse is defined as "a curve generated by a point moving so that the sum of its distances from two fixed

points, called the 'foci,' is constant and is equal to the longest diameter or major axis."

A line through the center perpendicular to the major axis is called the "short diameter" or "minor axis." To find the foci, draw an arc with its center at one end of the minor axis and a radius equal to one-half the major axis. This will cut the major axis at the foci F_1 and F_2 (Fig. 273).

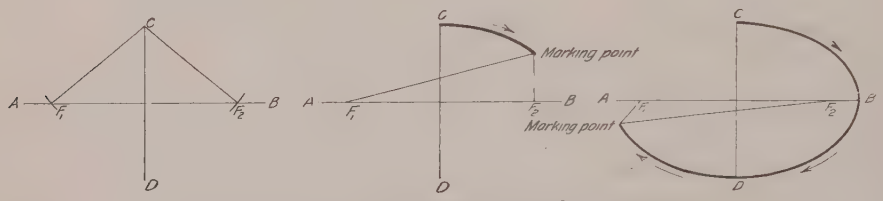


Fig. 274.—To draw an ellipse by pin and string method.

170. To Draw an Ellipse. —The easiest method for large work is the pin-and-string method. Given the major and minor axes (Fig. 274): Locate the foci as described in the previous paragraph. Drive pins at points F_1, C and F_2, and tie a cord tightly around the three pins. Then remove the pin C and move a marking point in the loop, keeping the cord taut. This will draw a true ellipse.

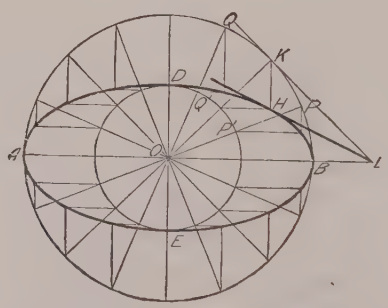


Fig. 275.—Two-circle method.

171. The concentric-circle method (Fig. 275) is a very accurate method for finding points on a required ellipse. With O as center, draw circles on the major and minor diameters. Draw a number of radial lines OP, OQ, etc., cutting the large circle at P, Q and the small circle at P', Q'. From P and Q draw vertical lines and from P' and Q' horizontal lines. Where the lines through P and P' cross, there is one point on the ellipse. The lines through Q and Q' give another point. Find as many points as necessary, and

through them draw the curve, sketching it in very lightly before using the irregular curve. A tangent at any point H may be found by dropping a perpendicular from the point to the outer circle, at K, and drawing an auxiliary tangent KL cutting the major axis produced at L. From L draw the required tangent LH.

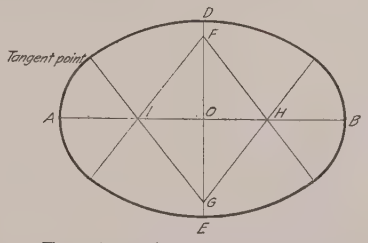


FIG. 276.—Approximate ellipse.

172. Approximate ellipses may be drawn with arcs of circles (see Art. 164). When the minor axis is at least two-thirds of the major axis, the four-center approximation shown in Fig. 276 is satisfactory. Make OF and OG each equal to AB minus DE. Make OH and OI each equal to three-fourths of OF. Draw FH, FI, GH and GI, extending then as shown. Draw arcs through points D and E with centers at G and F and through A and B with centers I and H.

CHAPTER XV

SHEET-METAL DRAFTING

173. Sheet-metal Drafting. There is a large class of metal work made from thin sheets of metal which are formed into the required shape by bending or folding up and fastening by rivets, seams, soldering, or welding. Figure 277 shows an air-condition-

FIG. 277.—Sheet-metal ducts. (*Photo by Bethlehem Steel Company.*)

ing duct installation made up of Bethlehem-steel sheets. For sheet-metal work, the drawings consist of the representation of the finished object and the drawing of the shape of the flat sheet, which when rolled or folded and fastened will make the object.[1]

[1] A great many thin metal objects are formed without seams by die-stamping or pressing a flat sheet into shape under very heavy presses. Examples range from

This second drawing is called the "development" or "pattern" of the piece, and making it comes under the term "sheet-metal pattern drafting."

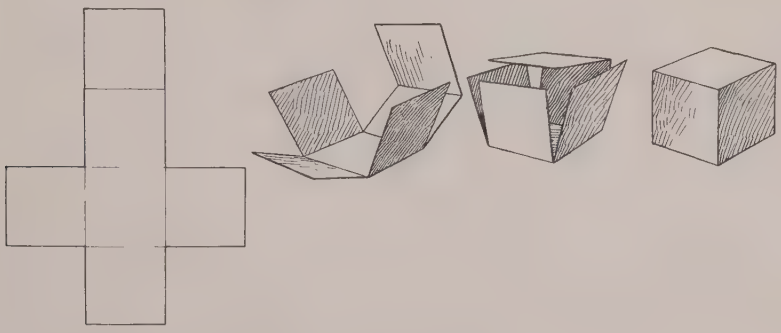


FIG. 278.—Pattern for a cube.

174. Development.—There are two general classes of surfaces: plane surfaces and curved surfaces. The six faces of a cube are

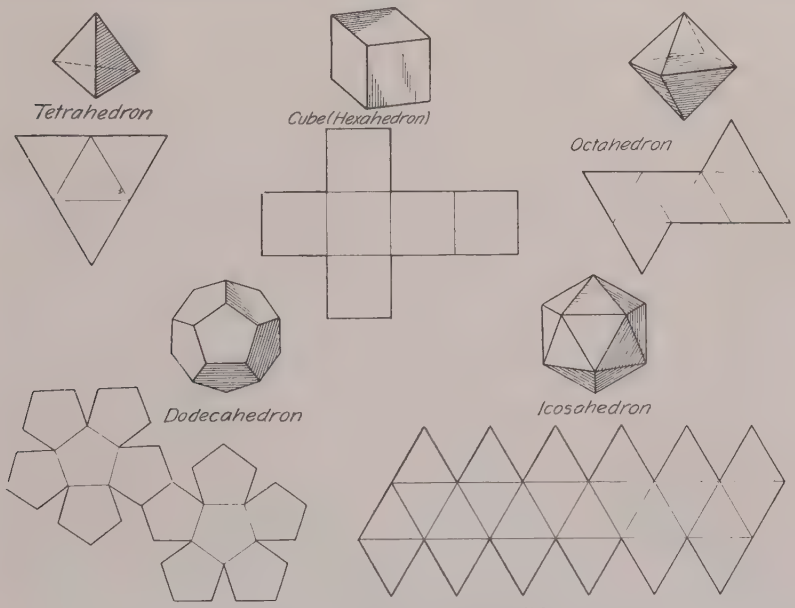


FIG. 279.—The five regular solids.

plane surfaces. The bases of a cylinder are plane surfaces, whereas the lateral surface is curved.

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brass cartridge cases to steel wheelbarrows. Still another division is made by "spinning," as brass and aluminum ware. In stamped and spun work the metal is stretched out of its original shape, and making blanks for it depends upon much technical knowledge and experience.

It is possible to cut a piece of paper so as to fold it up into a cube, as in Fig. 278. The shape cut out would be the *pattern* of the cube. Those who have studied solid geometry recall that there are five regular solids and that their patterns are made as shown in Fig. 279. A good understanding of the nature of developments may be had by laying out the foregoing patterns and folding them to form the figures, using a rather stiff drawing paper. The joints can be easily secured with cellulose tape.

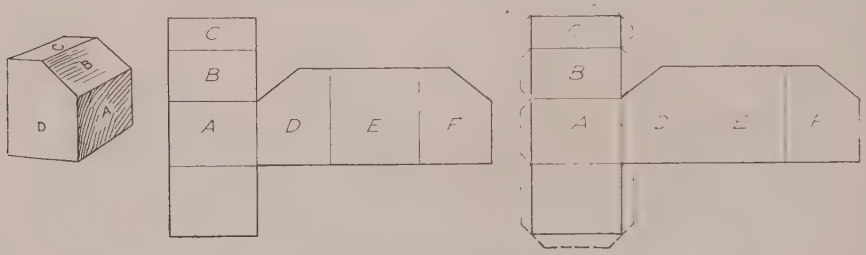


Fig. 280.—A pattern showing lap.

Thus the pattern for any piece which has plane surfaces may be made by first deciding where the seam is to be (usually, for economy of solder or rivets and time, it is taken on the shortest line), then opening up each face in order, showing it in its true size. One example, the development of a prism, is illustrated in Fig. 280. The lines inside the pattern are called "folding" or "crease"

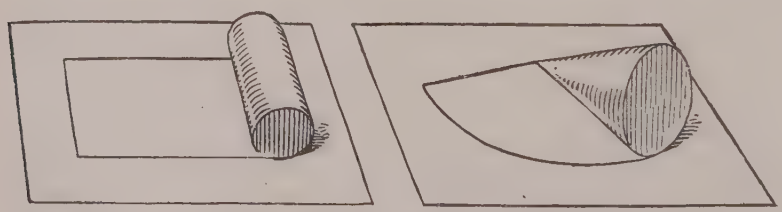


Fig. 281.—Cylinder and cone.

lines. The dotted lines on the second figure indicate extra material to allow for lap in making joints.

In geometry we learn that a cylinder may be thought of as a prism with an infinite number of sides. The development of a cylinder, then, would be a rectangle having a width equal to the height of the cylinder and a length equal to the distance around the cylinder. Figure 281 shows pictorially the developed surface of a cylinder and also of a cone.

The length of the pattern of a prism or cylinder is measured on a straight line called the *stretchout line*. This line is the stretched-out length of the shortest distance around the figure. When the base is perpendicular to the axis, it will roll out into a straight line and form the stretchout. If the prism or cylinder does not have a base perpendicular to the axis, a "right section" must be taken in order to get a straight stretchout.

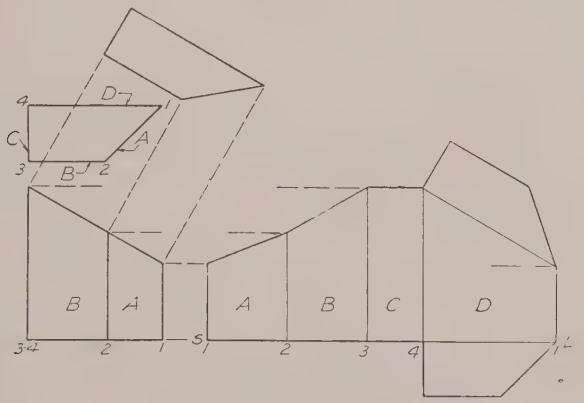


FIG. 282.—Development of a prism.

175. Development of Prisms.—To develop the prism in Fig. 282, draw the stretchout line *SL*, and on it lay off 1-2, 2-3, 3-4 and 4-1, obtained from the top view. This gives the length of the

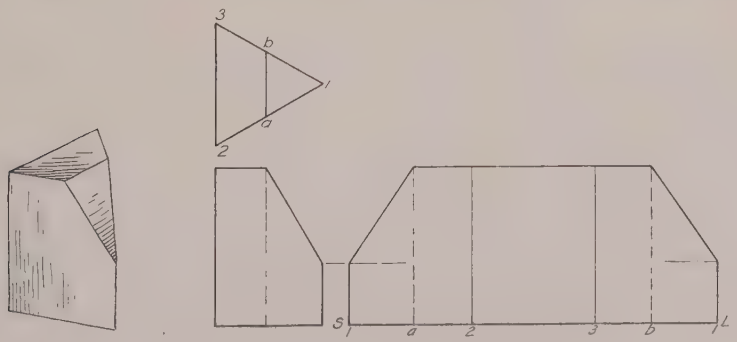


FIG. 283.—Development of a prism.

stretchout and the true distances between the vertical edges. At points 1, 2, 3, 4 and 1 on the stretchout draw vertical "crease lines" equal in length to the corresponding edges of the prism. These lengths may be easily projected across from the front view.

The true size of the inclined surface is found by the method of auxiliary projection (Chap. VII) and attached to one of the sides in its proper relation. The development of the bottom may be added if desired.

To develop the lateral surface of the triangular prism (Fig. 283), draw the stretchout line *SL*, and lay off the distances 1-*a*,

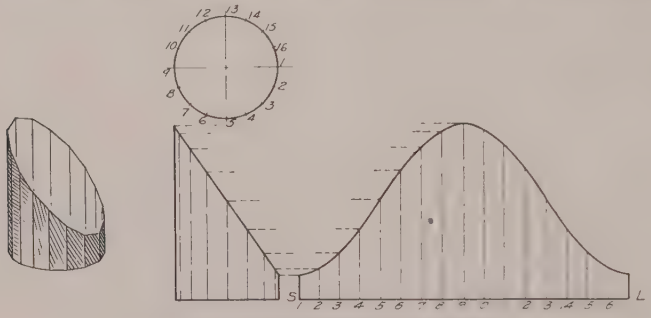


Fig. 284.—Development of a cylinder.

a-2, 2-3, 3-*b*, *b*-1, taken from the top view. Points *a* and *b* do not locate crease lines but are required to find the line of the cut. Such extra "measuring lines" are often necessary.

176. Development of Cylinders.—Consider a cylinder as being a many-sided prism. To develop the cylinder (Fig. 284), assume the position of any convenient number of imaginary edges. For ease of working these are equally spaced, which makes it possible

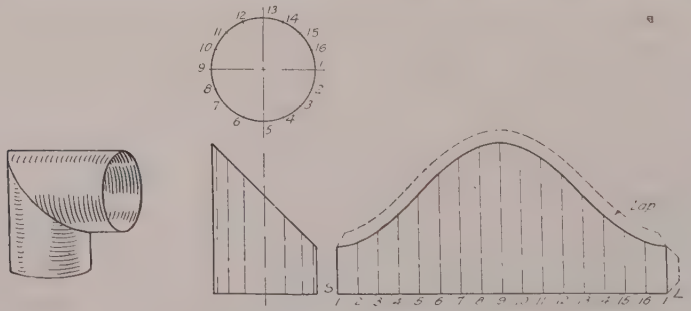


Fig. 285.—Pattern for a square elbow.

to obtain the length of the stretchout by stepping off as many spaces along *SL* as there are on the top view. At each point on the stretchout draw a vertical "measuring line." Project the length of each imaginary edge across from the front view to the corresponding line of the development and draw a smooth curve through these points of intersection.

Since the surface is curved, the stretchout as obtained is only approximate. The more edges assumed, the closer will be the approximation; but it is seldom necessary to have the points less than one-fourth inch apart. The accuracy in length of the stretchout may be tested by measuring on it the figured length of the circumference, which equals 3.1416 × the diameter, or πd.

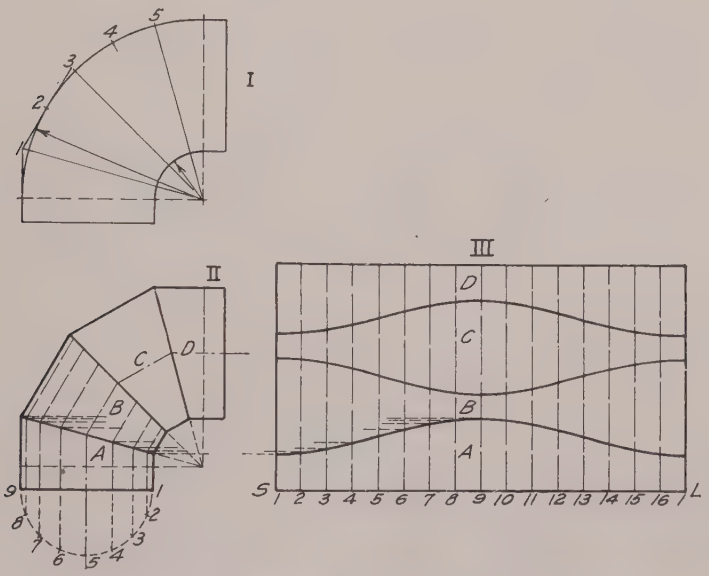


FIG. 286.—Pattern for a four-piece elbow.

177. To Draw the Pattern for a Two-piece or Square Elbow (Fig. 285).—This elbow consists of two cylinders cut off at 45°, so only one need be developed. The explanation of Fig. 284 applies to this figure. Lap is allowed as indicated.

178. The development of a four-piece elbow is illustrated in Fig. 286. To draw the elbow: First draw arcs having the desired inner and outer radii as shown at I. Divide the outer quarter circle into six equal parts. Draw radial lines from points 1, 3 and 5 to locate the joints. Draw tangents to the arcs at points 2 and 4 and complete the figure as shown at II, by tangents to the inner quarter circle. With this view completed, we are ready to start development. Draw a circle representing the cross section of the pipe (one-half of this view is sufficient). Divide it into a number of equal parts, and lay out the stretchout line with the same equal parts. From the circle project to the elevation to locate the imagi-

nary edges. The pattern for the first section is obtained by projecting across from the elevation in the same way as Fig. 284.

The patterns for the four pieces may be cut without waste from a rectangular piece if the seams are made alternately on the inside, or throat, line and the outside line. To draw the pattern for the second section, extend the measuring lines of the first section, and with the dividers take off the lengths of the imaginary edges on the front view, starting with the longest one. The third

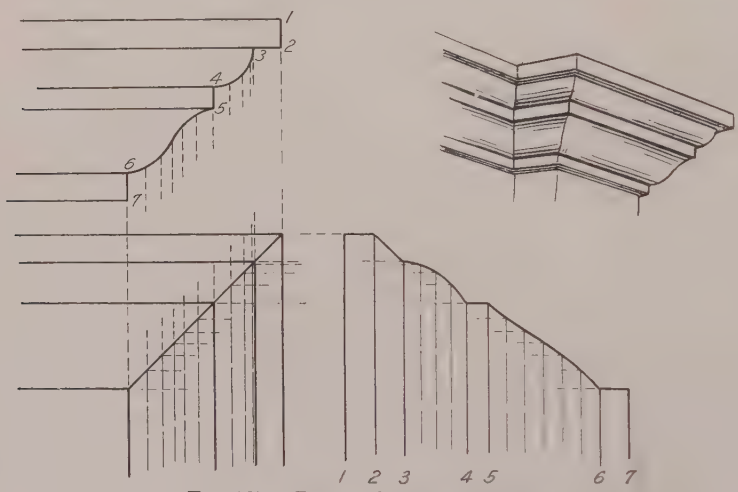


FIG. 287.—Pattern for a return miter.

and fourth sections are made in a similar way. Since the curve is the same for all sections, one only need be plotted.

179. Galvanized-iron moldings and cornices are made up of a combination of cylinder and prism parts. A practical problem in developments is making the pattern for a piece mitered to "return" around a corner as shown in the sketch of Fig. 287. An inspection of the figure shows the method of working to be the same as Fig. 284, the section of the molding taking the place of the top view and having its length laid out on the stretchout line.

180. Development of Pyramids and Cones. —In the case of prisms and cylinders the stretchout was a straight line with the measuring lines perpendicular to it and parallel to each other. And as their edges were all parallel to the front plane, their true lengths were always shown in the front view. Pyramids and cones or any objects larger at one end than at the other will not

roll straight; hence their stretchouts are not straight lines. Also, since they have sloping sides, their edges will not always show in their true lengths.

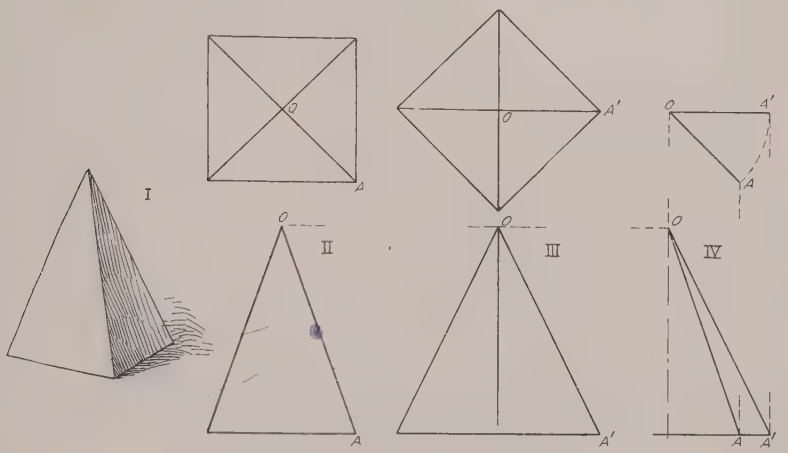


FIG. 288.—True length of a line.

181. To find the true length of a line, revolve the line until it is parallel to one of the planes of projection. Its projection on that plane will then be the true length of the line. The pyramid

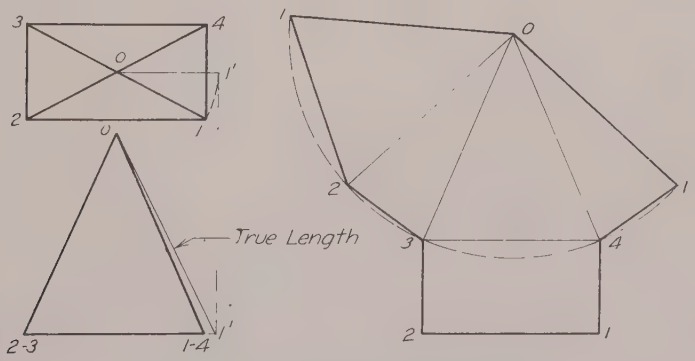


FIG. 289.—Development of a pyramid.

at I in Fig. 288 is shown by top and front views at II. The edge *OA* does not show in its true length in either view. However, if we draw the pyramid in the position shown at III, the true length of *OA* is shown in the front view. At III the pyramid has been revolved from the position of II about a vertical axis until the line *OA* is parallel to the vertical plane. At IV the line *OA* is shown

before and after revolving. Thus the construction for finding the true length of a line is as follows: In the top view with radius OA

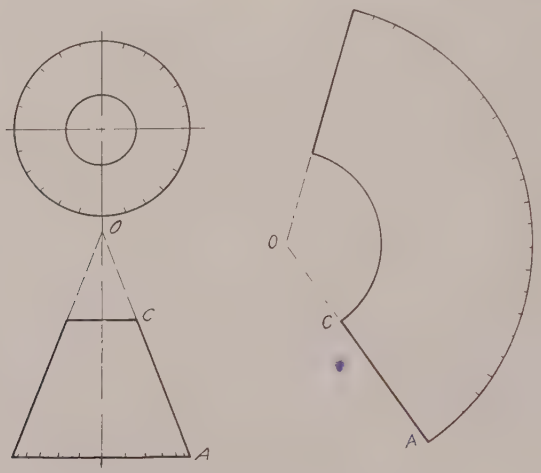


FIG. 290.—Frustrum of a cone.

and center O revolve the top view of OA until it is horizontal, project the end of the line down to meet a horizontal line through the front view of A. Join this point of intersection with the front view of O. The true length is shown at OA'.

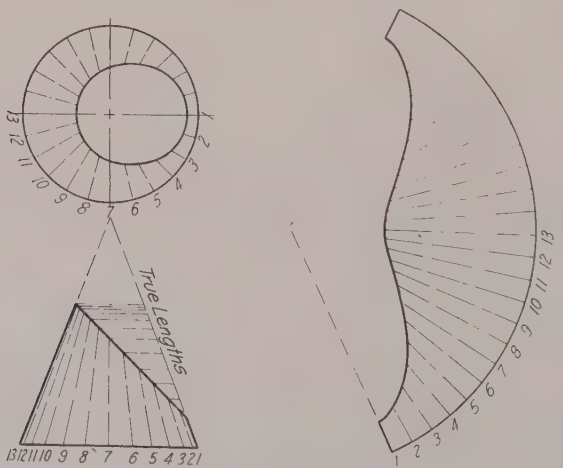


FIG. 291.—Truncated cone.

182. To Draw the Pattern for a Rectangular Pyramid (Fig. 289).—Find the true length of one of the edges by swinging it

around as shown. With this true length as a radius draw an arc of indefinite length for a stretchout line. On this mark off as chords the four edges of the base 1-2, 2-3, 3-4, 4-1. Connect these points with each other in turn, and draw the crease lines by joining each point with the center.

183. To Draw the Pattern for a Cone.—By referring back to Fig. 281, it will be seen that the stretchout line for a cone is a circle arc with a radius equal to the slant height of the cone. Considering the cone as a many-sided pyramid, draw on the top view a convenient number of imaginary edges (elements), using equal spacing for convenience. With the slant height taken from the front view as a radius (*OA* in Fig. 290), draw an arc of indefinite length as a stretchout. On this, step off as many spaces as were assumed in the top view and at the same distances apart. Connect end points with the center. The resulting sector is the developed surface. If the cone is cut off straight across as in Fig. 290, draw another arc with *OC* as a radius after developing the full cone.

184. If the cone is cut off at an angle, as in Fig. 291, first develop the full cone, drawing the developed position of each element and numbering them to avoid mistakes. Then find the true length of each element from the base to the cut surface by revolving it around the axis until it is parallel to the front plane or, in other words, by projecting it across to the outside line in the front view. Lay off these true lengths on the corresponding lines on the pattern and connect the points. The elements and lines have been stopped at the cut surface to preserve clearness.

185. Development of a Transition Piece.—A transition piece is used to connect a pipe of one shape with another of a different shape. Transition pieces are made up of parts of different kinds of surfaces and are developed by triangulation. The example shown in Fig. 292 connects a round pipe with a rectangular one. From the picture it is seen that this piece is formed of four triangles, between which are four conical parts, with apexes at the corners of the rectangular opening and bases each one-quarter of the round opening.

Starting with the cone whose apex is at *A*, divide its base 1-5 into a number of equal parts as 2, 3, 4, and draw the lines *A*-2, *A*-3, *A*-4, giving triangles approximating the cone. Find the true length of each of these lines. This is done in practical work by constructing a separate diagram, as at I, knowing that the true

length of each line is the hypotenuse of an imaginary triangle whose altitude is the altitude of the cone and whose base is the length of the top view of the line.

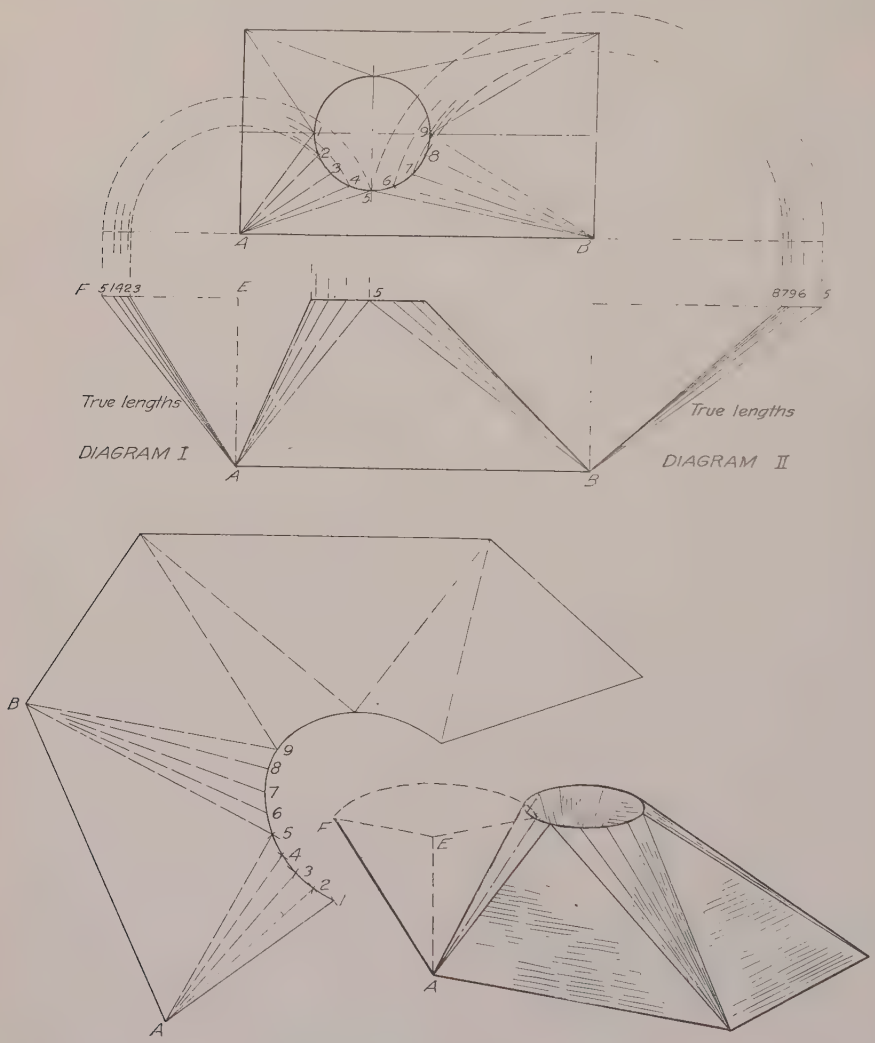


Fig. 292.—Development of a transition piece.

On the front view draw the vertical line AE as the altitude of the cone. On the base EF lay off the distances A-1, A-2, etc. This is done in the figure by swinging each distance about the point A in the top view and dropping perpendiculars to EF. Connect the points thus found with the point A in diagram I, thus obtaining the desired true lengths. Diagram II, constructed

in the same way, gives the true lengths of lines B-5, B-6, etc., of the cone whose apex is at B. After the true-length diagrams are constructed, start the development, with the seam at A-1. Draw a line A-1 equal to the true length of A-1. With 1 as a center and radius 1-2 taken from the top view, draw an arc. Intersect this arc with an arc from center A and radius equal to the true length of A-2, thus locating the point 2 on the develop-

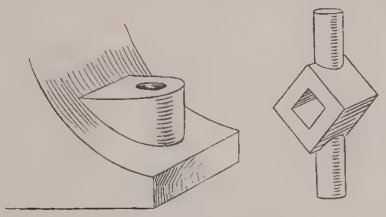


FIG. 293.—Intersections.

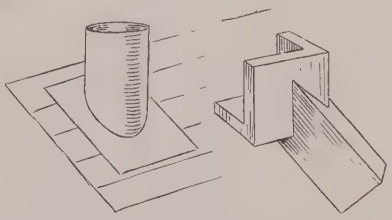


FIG. 294.—Intersections.

ment. With 2 as center and radius 2-3 draw an arc and intersect it by an arc with center A and radius of the true length of A-3. Proceed similarly with points 4 and 5 and draw a smooth curve through the points 1, 2, 3, 4 and 5, thus found. Then attach the true size of the triangle A-5-B, locating point B on the development by intersecting arcs from A with radius AB taken from the top view, and from 5 with radius the true length of B-5. Continue until the piece is completed.

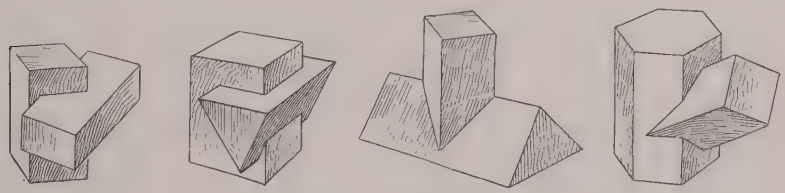


FIG. 295.—Intersecting prism.

186. Intersections.—Whenever surfaces come together, there is a line common to both, called a "line of intersection." In Figs. 293 and 294 a number of lines of intersection are shown. It is necessary for both the machine designer and the sheet-metal worker to be able to locate a line of intersection when one occurs.

187. Intersecting Prisms.—Several examples of intersecting prisms are illustrated in Fig. 295.

To draw the intersection of two prisms, first start the orthographic views. In Fig. 296 a square prism passes through a hexagonal prism. Through the front edge of the square prism pass a plane parallel to the vertical plane. The top view of this

plane appears as a line AA. The intersection of the plane AA and one of the faces of the vertical prism shows in the front view as line aa and is crossed by the front edge of the square prism at

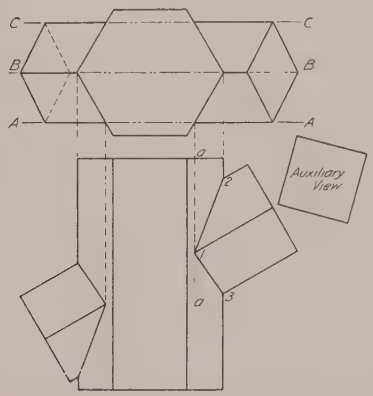


Fig. 296.—Intersections.

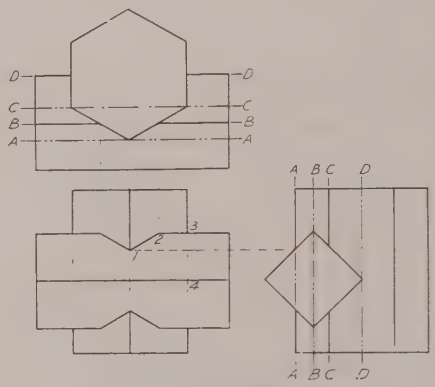


Fig. 297.—Intersecting prism.

point 1, which is a point on both prisms and, therefore, a point in the desired line of intersection. Plane BB is parallel to plane AA and contains an edge of the vertical prism and an edge of the inclined prism, which meet at point 2 in the front view. Plane BB also determines point 3.

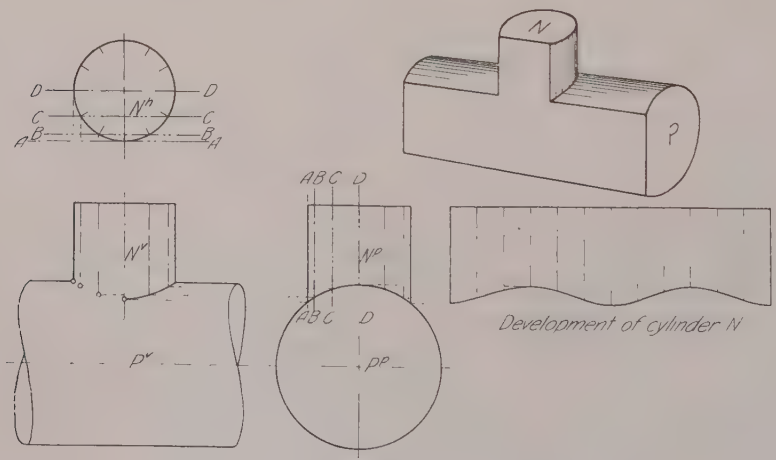


Fig. 298.—Intersection of two cylinders.

These planes are called "cutting planes," and they may be used for the solution of most problems in intersections. For intersecting prisms, pass planes through all the edges of both prisms

within the limits of the line of intersection. Where the lines that are cut from both prisms by the same plane cross, there is a point on the required line of intersection. In Fig. 297 four cutting planes are required. The limiting planes are *AA* and *DD*, as a plane in front of *AA* or back of *DD* would cut only one of the prisms

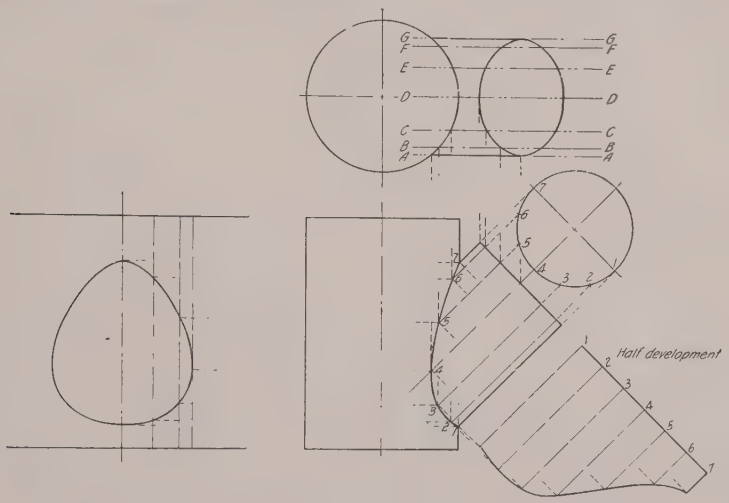


Fig. 299.—Intersection and development of two cylinders.

188. Intersecting Cylinders.—To draw the line of intersection of two cylinders (Fig. 298): Since there are no edges on the cylinders, it will be necessary to assume positions for the cutting planes. Plane *AA* contains the front line of the vertical cylinder and cuts a line from the horizontal cylinder. Where these two lines intersect in the front view, there is a point on the required curve. Each plane cuts lines from both cylinders, which intersect at points common to both cylinders. The development of the vertical cylinder, obtained by the method of Art. 176, is shown in the figure.

The solution for an inclined cylinder is given in Fig. 299, where the positions of the cutting planes are located by an auxiliary view. To develop the inclined cylinder, the auxiliary view is used to get the length of the stretchout. If the cutting planes have been chosen so that the circumference of the auxiliary view is divided into equal parts, the measuring lines will be equally spaced along the stretchout.

To develop the portion of the vertical cylinder having the hole for the inclined cylinder, lay out a portion of the stretchout and project from the front view to the measuring lines as shown.

189. Intersecting Cylinders and Prisms.—The intersection of a cylinder and a prism is found by the use of cutting planes as already described. In Fig. 300 a triangular prism intersects a cylinder. The planes *A*, *B*, *C* and *D* cut lines from the prism and

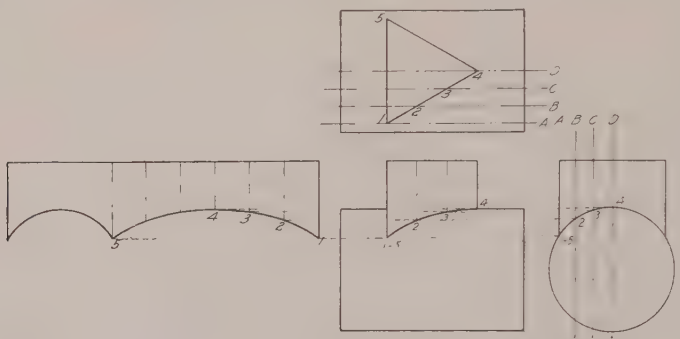


FIG. 300.—Intersection and development of cylinder and prism.

lines from the cylinder which cross in the front view and determine the curve of intersection, as shown. The development of the triangular prism is found by taking the length of the stretchout line from the top view and the lengths of the measuring lines from the front view. Since one plane of the triangular prism is perpendicular to the axis of the cylinder, the curve of intersection on that face is the radius of the cylinder.

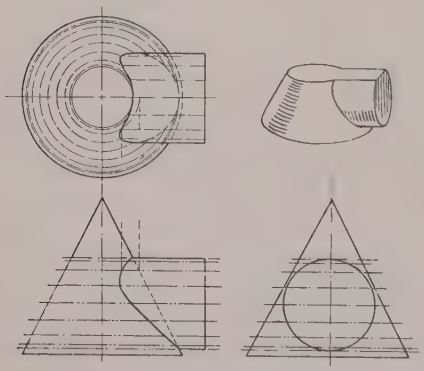


FIG. 301.—Cylinder and cone.

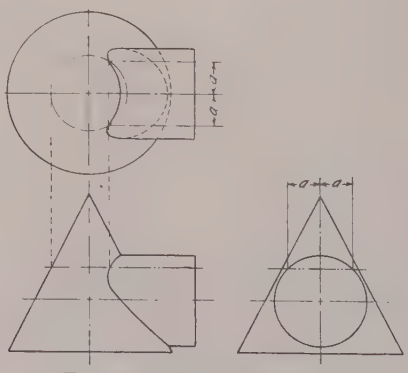


FIG. 302.—A cutting plane.

190. Intersection of Cylinders and Cones.—The intersection of a cylinder and a cone may be found by passing planes parallel to the horizontal plane, as shown in Fig. 301. Each plane will cut a circle from the cone and two straight lines from the cylinder.

The straight lines of the cylinder cross the circle of the cone in the top view at points on the curve of intersection, which are then projected to the front view, as in Fig. 302, where the construction is shown for a single plane. Use as many planes as are necessary to obtain a smooth curve.

191. Intersection of Planes and Curved Surfaces.—The line of intersection of a cone cut by a plane *MM*, as in Fig. 303, may be found by horizontal cutting planes *A*, *B*, *C*, *D*. Each plane cuts a circle from the cone and a straight line from the plane *MM*, thus locating points common to both the plane *MM* and the cone, as shown in the top view. These points, when projected to the front view, give the curve of intersection.

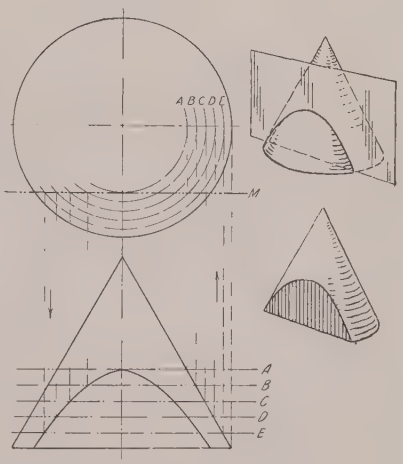


Fig. 303.—Cone and plane.

The intersection at the end of a connecting rod is found by passing planes perpendicular to the axis, which cut circles as shown

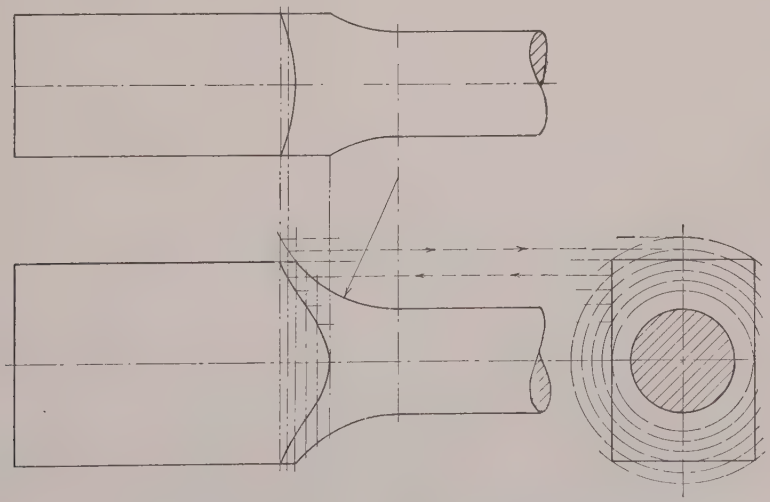


Fig. 304.—Intersection of plane and turned surface.

in the end view of Fig. 304. The points at which these circles cut the "flat" are projected back as points on the curve.

192. Development of a Measure.—To draw the development of a measure (Fig. 305): Draw the view shown with the half circles at top and bottom in Fig. 306. Observe that the body is a frustum

FIG. 305.

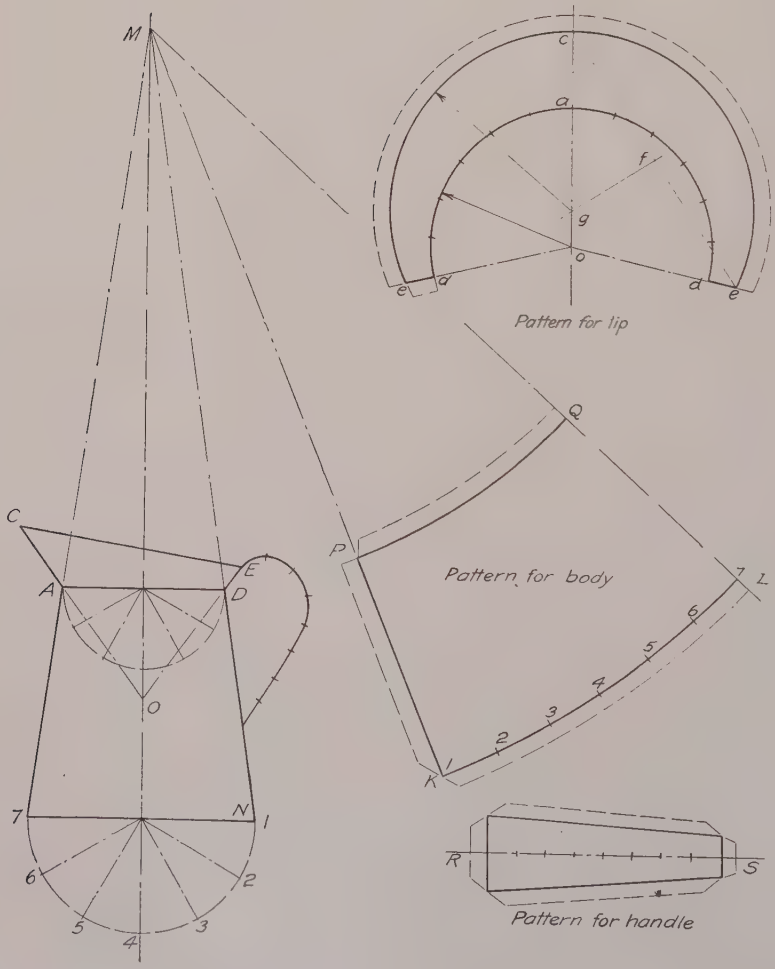


FIG. 306.—Pattern for a measure.

of a cone. Extend the outline to complete the cone. With MN as a radius, draw an arc. Step off one-half the circumference of the base on this arc, and draw the radial lines MK and ML. With M as a center and MD as a radius, draw arc PQ, completing the development of the body. Add the necessary allowance for lap.

To develop the handle, divide it into a number of spaces and step them off on the stretchout RS. At R lay off one-half the width of the upper end of the handle on each side and at S one-half the width of the lower end of the handle on each side of the stretchout. Add allowance for laps and hems. The true development of the lip would require the drawing of lines through each point and finding the length of each line as described for the truncated cone (Fig. 291). The usual practical method is as follows: On a center line oa draw an arc with OA as a radius, and space one-half the circumference of the top of the body on each

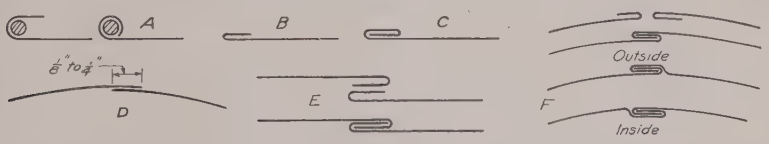


Fig. 307.—Wiring, seaming and hemming.

side, as shown by dad. Draw the radii od. Increase OA by $ac = AC$, and increase od by $de = DE$, as obtained from the elevation. Draw ce and the perpendicular bisector of ce intersecting the center line at g. With g as a center and gc as a radius draw arc ece to complete the pattern. Add the necessary material for seams and hems.

193. Seams and Laps. The basis of sheet-metal pattern drafting is development. For practical work it is necessary to know the processes of wiring, seaming and hemming and the allowances of material to be made. Open ends of articles are usually reinforced by enclosing a wire in the edge, as shown at A in Fig. 307. The amount added to the pattern may be taken as two and one-half times the diameter of the wire. Edges are also stiffened by hemming. Single- and double-hemmed edges are shown at B and C. Edges are fastened by soldering on lap seams (D), folded seams (E) or, the commonest way, by grooved seams, shown in three stages, both inside and outside, at F. An important consideration in allowing lap on patterns is the shape of the space left at the corners to prevent thick places in the seam. This is called "notching" and is illustrated on Fig. 306.

CHAPTER XVI

ARCHITECTURAL DRAFTING

194. Architectural drawings are concerned with the representation and specification of buildings and structures of various kinds. The general principles are the same as for other technical drawings but there are certain methods of representation, conventional symbols, and practices which are necessary because of the relatively small scale which must be used for architectural plans.

FIG. 308.—Pen and ink perspective of a house.

195. Classes of Drawings. There are three general classes of architectural drawings: (1) preliminary sketches, (2) display and competitive drawings and (3) working drawings.

196. Preliminary Sketches.—These are freehand studies of the arrangement of rooms, general appearance of elevations and other matters for study and consideration. Very small thumbnail sketches are made at first, somewhat in proportion but without using the scale. Schemes which promise a satisfactory solution are then worked up in larger freehand sketches to approximate scale. Squared paper is convenient for this purpose. Tracing paper is often used to work out and preserve different arrangements by making one sketch over another.

197. Display and Competitive Drawings.—These are more or less elaborate preliminary drawings of a proposed building. Plans and elevations, often including a perspective, are used but without working information. They are rendered in water color, pen and ink, pencil or crayon to make them legible and attractive. A pen and ink perspective of a house is shown in Fig. 308.

198. Working Drawings.—These form the most important class of drawings and include plans, elevations, sections and detail draw-

FIG. 309.—A Roman alphabet.

ings which, when read with the specifications for details of materials, finish, etc., give the working information for the erection of the building. (Working drawings for the house shown in Fig. 308 are given in Figs. 320 to 324.)

199. Scales.—The architects' scale is described in Arts. 13 and 14. Ordinary house plans and plans for small buildings are drawn to the scale of $\frac{1}{4}'' = 1'$. The usual scale for larger buildings is $\frac{1}{8}'' = 1'$. Plot plans (Art. 208), may be drawn at $\frac{1}{16}'' = 1'$ or $\frac{1}{32}'' = 1'$. Larger scales are used for drawings of parts which cannot be shown with sufficient detail on the small scale

drawings. Wall sections may be drawn at 1″ = 1′ or 1½″ = 1′. Other scales used for various details include ½″ = 1′; ¾″ = 1′; 3″ = 1′, 6″ = 1′ and full size.

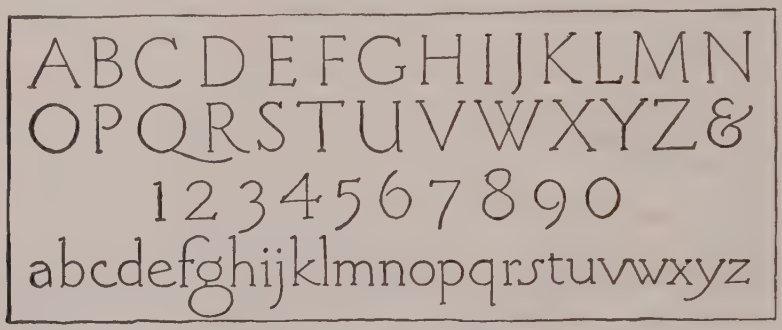


Fig. 310.—Single-stroke Roman.

200. Lettering and Titles.—The traditional lettering used by architects is based upon the Old Roman alphabet. A Roman alphabet is shown in Fig. 309. The letters may be "solid" or in "outline." For architectural working drawings the lettering is usually done in light single-stroke Roman, as shown in Fig. 310, or with plain terminals. However, some architects use the single-stroke letters of Figs. 28 and 30 or Figs. 35 and 38, for office lettering on working drawings.

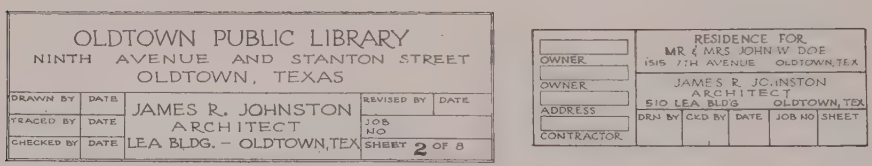


Fig. 311.—Titles.

Titles may be designed with single-stroke Roman letters or with the Roman letters of Fig. 309. The titles shown in Fig. 311 indicate the usual content and treatment of titles for architectural drawings.

201. Sill Details.—Sill construction for braced framing and for box-sill construction, as used for western framing, are shown in Fig. 312. Where brick veneering is used, the foundation wall must be increased as shown. Note the metal shield for protection against termites.

202. Cornice Details.—The walls and roofs of houses are joined by cornices. Box cornices, which conceal the rafters, are shown at *A* and *C* of Fig. 313. An open cornice, which exposes

the rafters, is shown at *B*. Note that the gutters may be either metal or wood. A box cornice with concealed gutter is illustrated on the working drawing of Fig. 323.

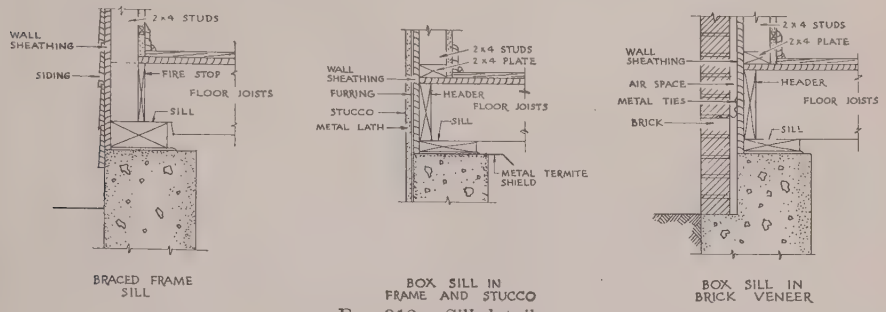


Fig. 312.—Sill details.

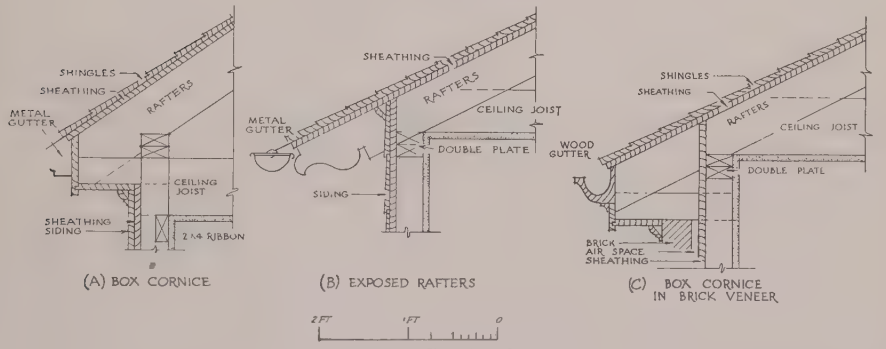


Fig. 313.—Cornice details.

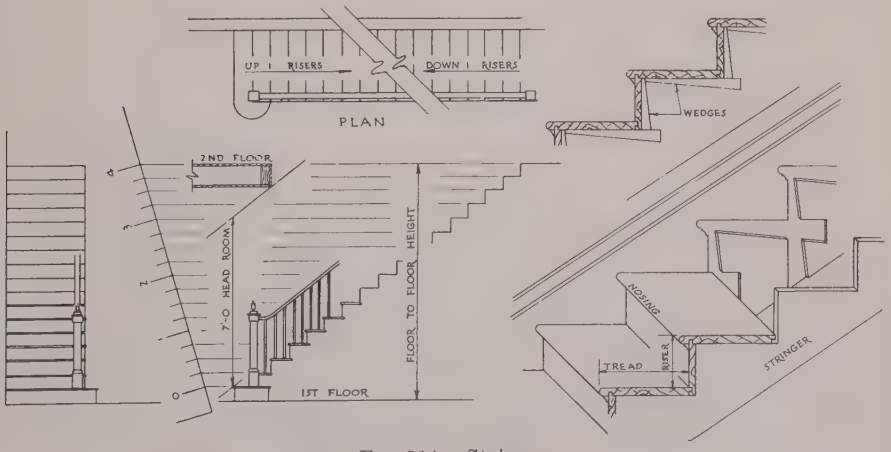


Fig. 314.—Stairs.

203. Stairways.—In drawing a stairway, first make a diagram to find the number of steps and space required. The riser, or

height from one step to the next, is from 6½″ to 7½″ and the width of the tread is such that the sum of riser and tread is about

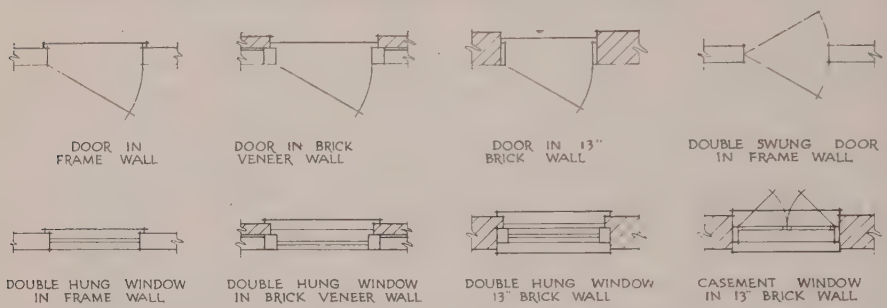

DOOR IN FRAME WALL
DOOR IN BRICK VENEER WALL
DOOR IN 13" BRICK WALL
DOUBLE SWUNG DOOR IN FRAME WALL
DOUBLE HUNG WINDOW IN FRAME WALL
DOUBLE HUNG WINDOW IN BRICK VENEER WALL
DOUBLE HUNG WINDOW 13" BRICK WALL
CASEMENT WINDOW IN 13" BRICK WALL

Fig. 315.—Symbols for doors and windows.

17½″. On the plan the lines drawn represent the edges of the risers and are drawn as far apart as the width of the tread, as

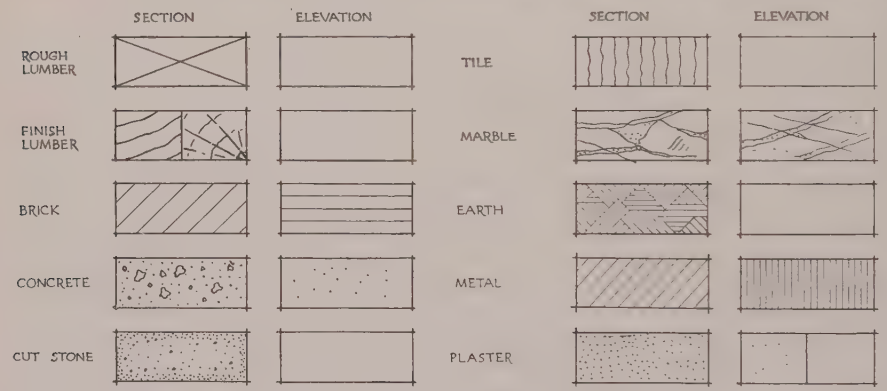


Fig. 316.—Symbols for building materials.

shown in Fig. 314. Note the use of the scale to divide the floor-to-floor height into the number of risers. On working drawings the

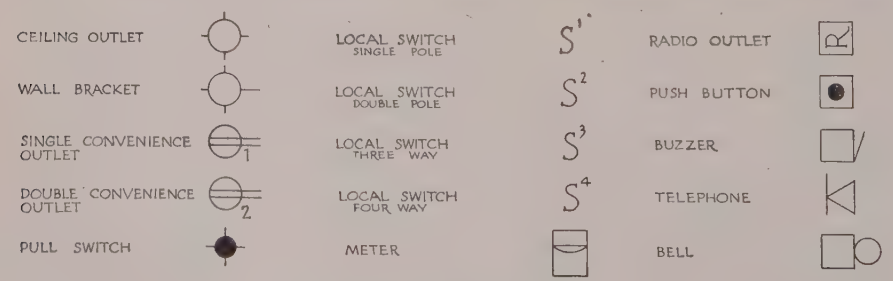


Fig. 317.—Electrical symbols.

entire flight is not drawn but is broken so as to show what is on the floor under it. The other end is shown on the floor above.

204. Symbols.—The small scale used on general plans makes it necessary to use symbols. Symbols for walls consist of lines

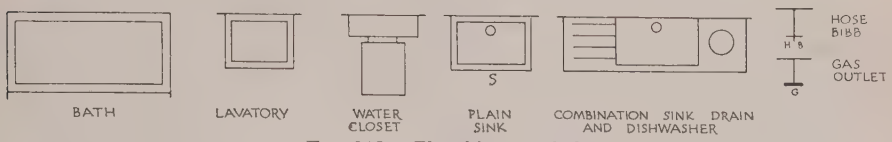


Fig. 318.—Plumbing symbols.

drawn to represent the thickness as in Fig. 315, which also shows the conventional methods of representing doors and windows. Symbols for building materials are shown in Fig. 316, electrical symbols in Fig. 317 and plumbing fixtures in Fig. 318.

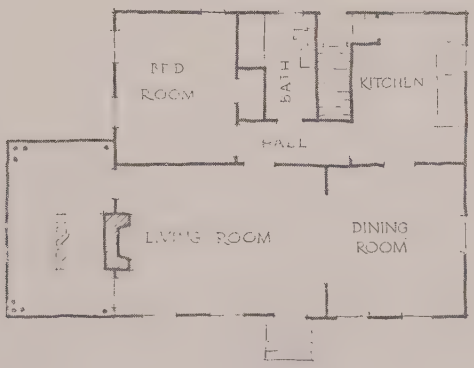


Fig. 319.—Sketch plan.

205. Plans.—A plan is a drawing of a horizontal section taken above the floor represented and at such places as will show the walls, doors, windows and other structural features. It is drawn to include all details relating to the story, such as built-in construction, cabinets, stairways, heating and plumbing and lighting outlets in walls and ceiling. Ordinary house plans are drawn to the scale of $\frac{1}{4}'' = 1'$.

A set of working drawings for a house is generally called a "set of plans" and includes a basement plan, plot plan, wall section, floor plan, elevations, details, etc. Such a set of plans for the house illustrated in Fig. 308 is shown in Figs. 320 to 324.

206. Floor Plan.—The sketch plan of a house is shown in Fig. 319. The floor plan developed from this sketch is shown in Fig. 320. The procedure is to draw a horizontal line representing the outside face of the front of the house; then draw the interior walls and the interior partitions. Frame walls are drawn 6″ thick.

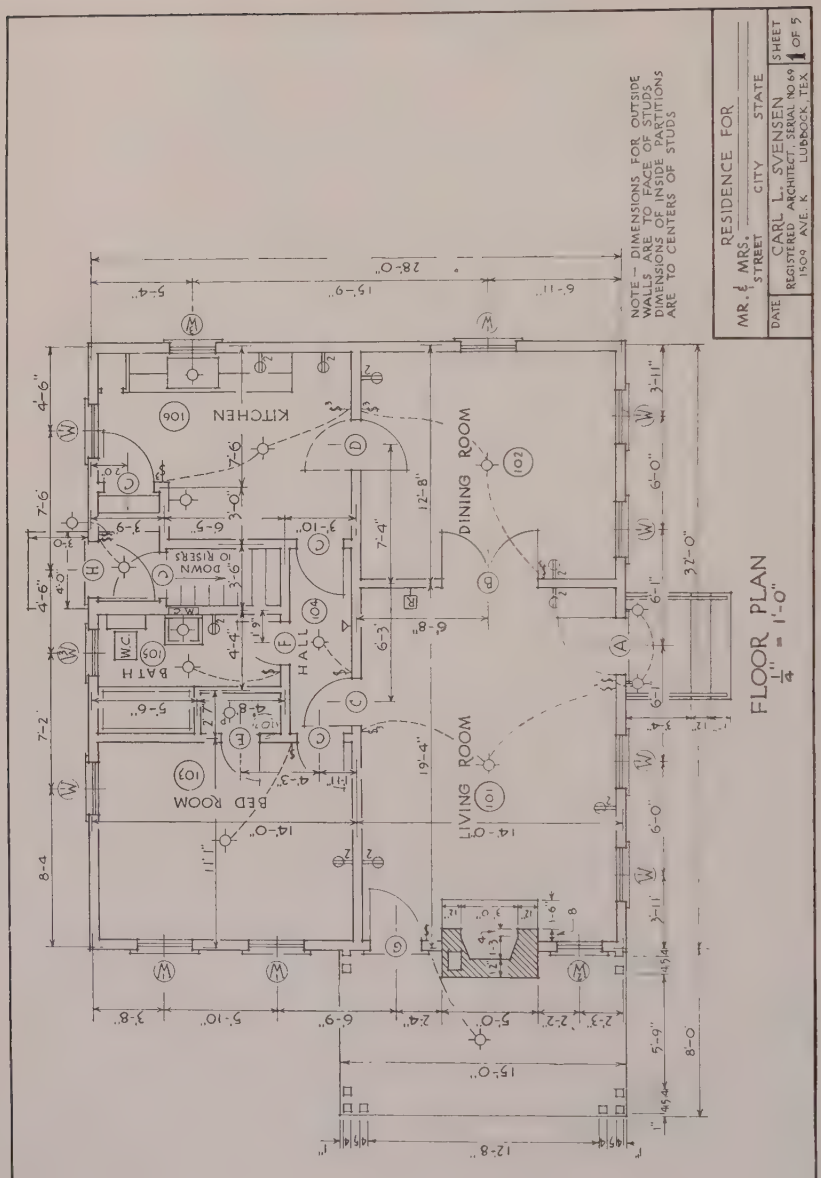


Fig. 320.—Floor plan.

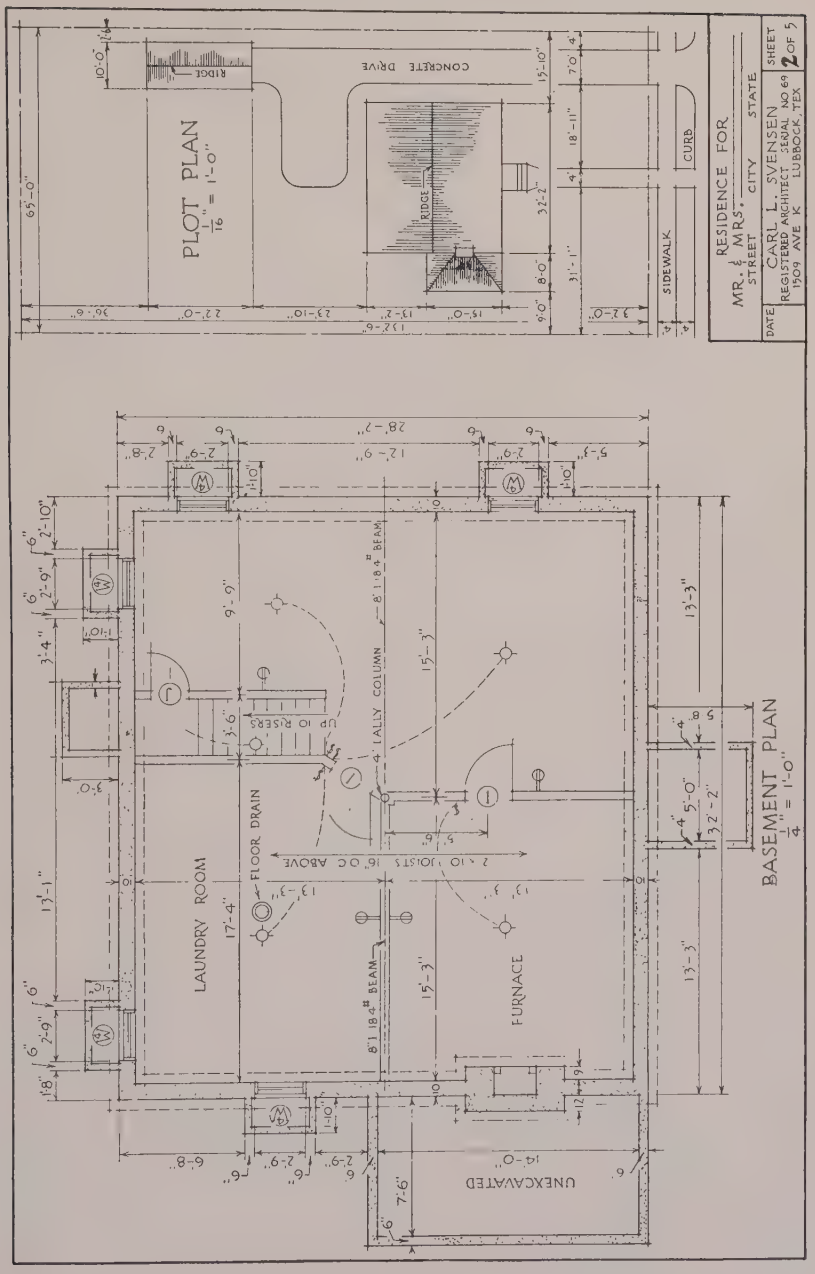


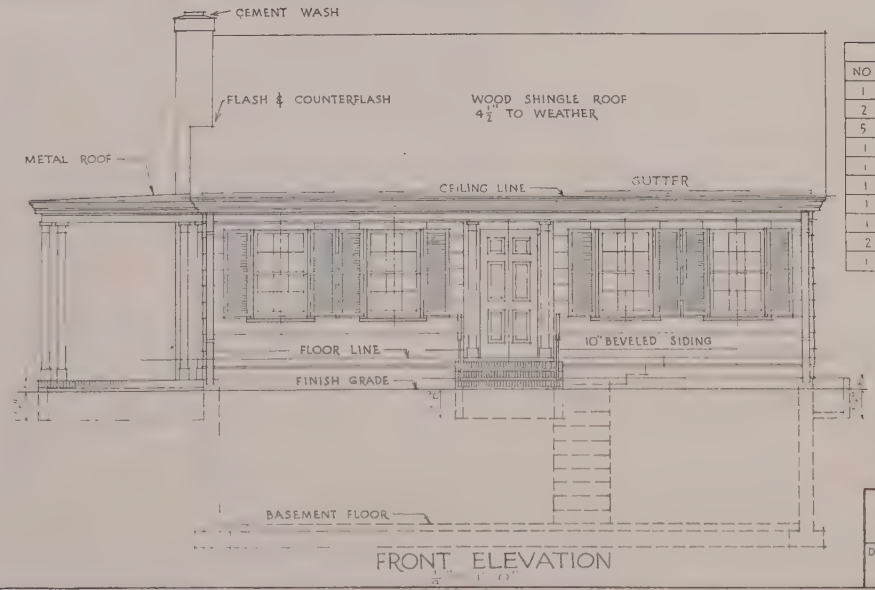
FIG. 321.—Basement plan and plot plan.

ROOM SCHEDULE

NO	ROOM	FLOOR	WALLS	CEILING	W'COAT	W C CAP	TRIM
101	LIVING ROOM	W. OAK	PLASTER	PLASTER	NO	NO	W PINE
102	DINING ROOM	W OAK	PLASTER	PLASTER	NO	NO	W PINE
103	BED ROOM	W OAK	PLASTER	PLASTER	NO	NO	W PINE
104	HALL	W OAK	PLASTER	PLASTER	NO	NO	W PINE
105	BATH	LINOLEUM	PLASTER	PLASTER	HARD PLASTER	W PINE	W PINE
106	KITCHEN	LINOLEUM	PLASTER	PLASTER	HARD PLASTER	W PINE	W PINE
107	CLOSET	W OAK	PLASTER	PLASTER	NO	NO	W PINE

WINDOW SCHEDULE

NO	MKD	FRAME	NO LTS	GLASS SIZE	SASH OPENING	THK	DESCRIPTION
9	1	W P.	12	10"x12"	2'-10" x 4' 6"	1 3/8	
1	2	W P.	12	8"x12"	2'-4" x 4'-6"	1 3/8	
2	3	W. P	12	8"x 8"	2' 4" x 3' 2"	1 3/8	
5	4	W P	2	10"x12"	2' 1" x 1' 4"	1 3/8	CELLAR SASH



DOOR SCHEDULE

NO	MKD	SIZE	THK	NO. PANELS	REMARKS
1	A	3 0 6 8	1 3/4	6	
2	B	2 4 6 8	1 3/8		
5	C	2 6 6 8	1 3/8	6	
1	D	2 6 6 8	1 3/8	6	DOUBLE SWING
1	E	2 0 6 8	1 3/8	6	
1	F	2 4 6 8	1 3/8	6	
1	G	2 8 6 8	1 3/4	6	
1	H	2 8 6 8	1 3/4	2	GLZD. 9 LTS.
2	I	2 6 6 8	1 3/8	?	
1	J	2 0 6 8	1 3/8	2	

RESIDENCE FOR
MR. & MRS. _____
STREET CITY STATE

DATE | CARL L. SVENSEN
REGISTERED ARCHITECT — SERIAL NO 69
1509 AVE K. LUBBOCK, TEX | SHEET 3 OF 5

FIG. 322.—Front elevation.

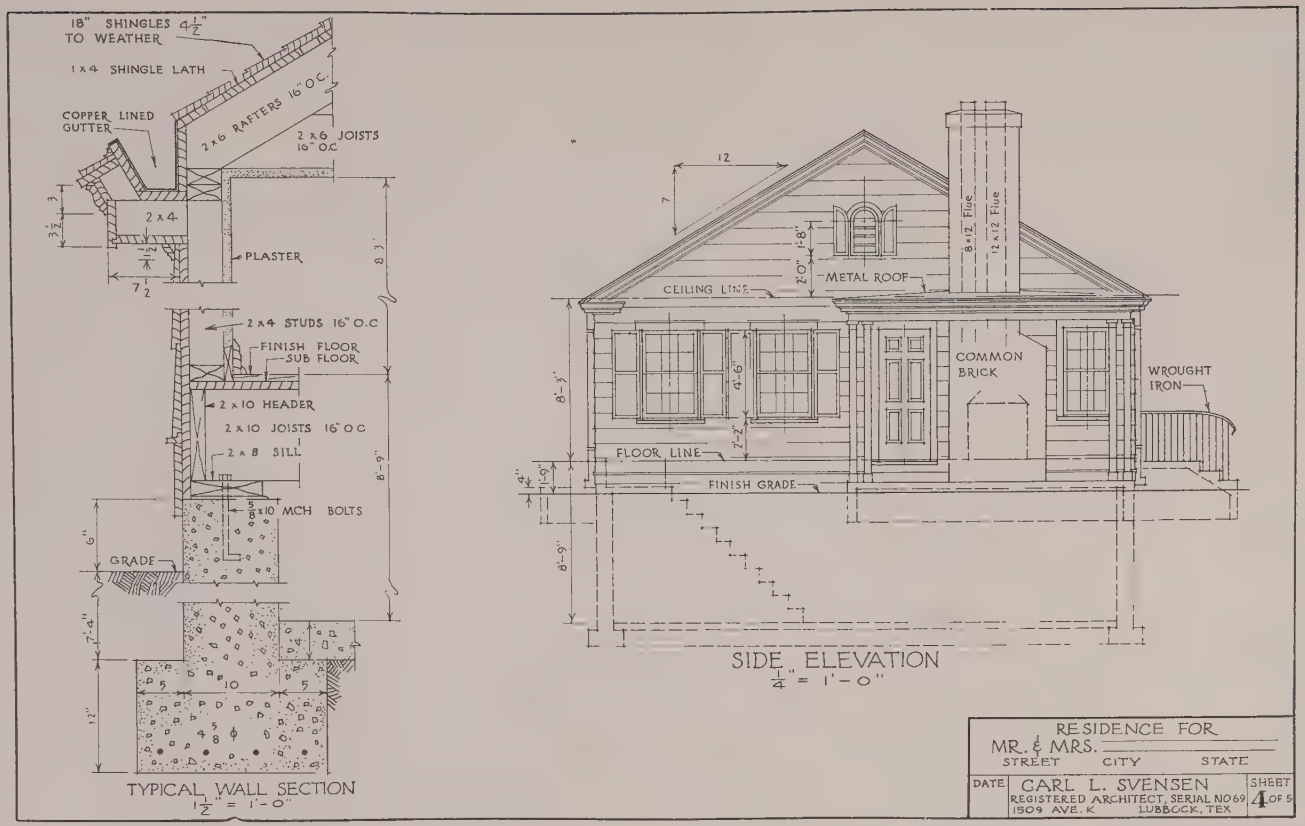


FIG. 323.—Side elevation.

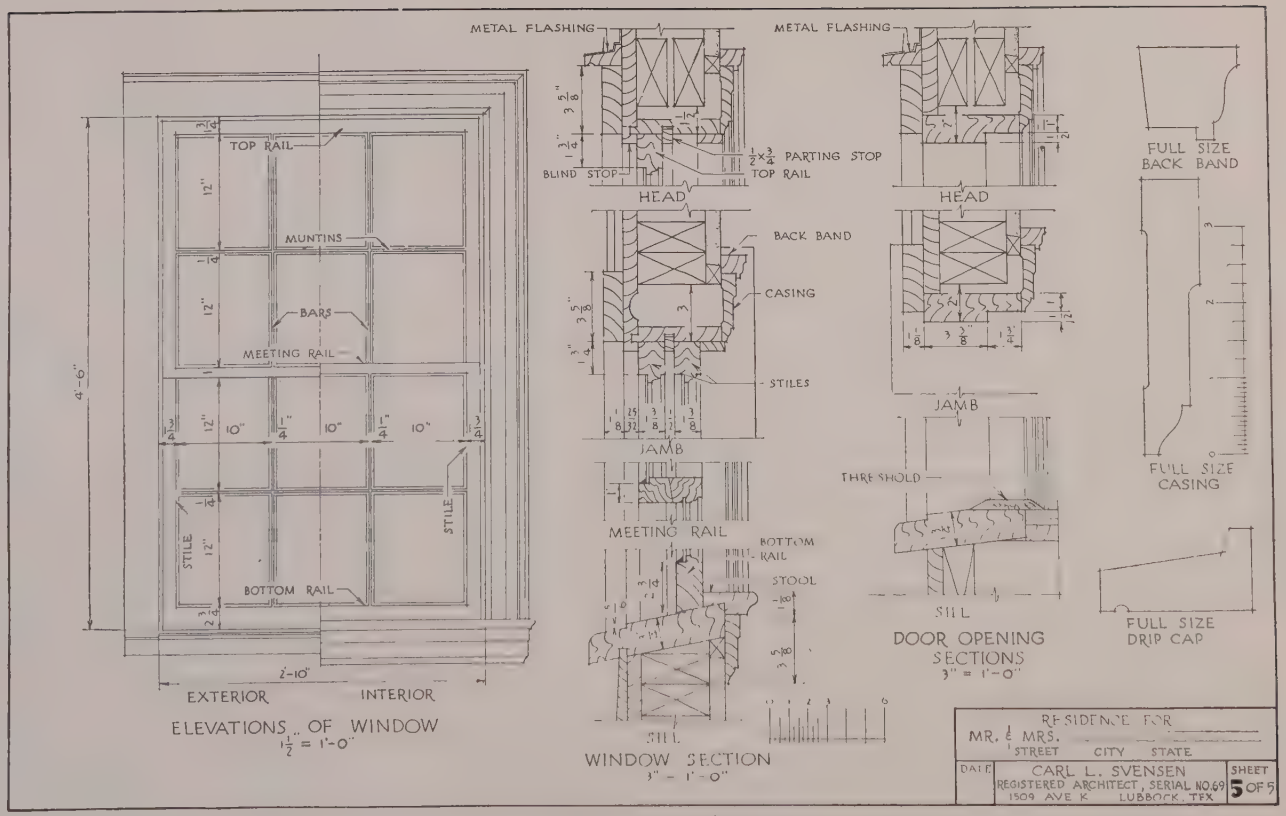


Fig. 324.—Details.

Locate the doors and windows and draw them with conventional symbols. For sizes of doors and windows refer to the schedules of Fig. 322.

The stairway shown can be laid out as described for Fig. 314, observing that a landing is used in place of one of the treads.

Only one floor plan is required for the house shown. When a second floor is to be drawn for a two-story house, it is best planned by laying a piece of tracing paper over the first-floor plan. Trace the exterior walls, and locate stairways and chimney flues. The interior partitions need not be continuous with the first floor. Closets should be provided in the bedrooms and elsewhere as required.

207. Basement Plan.—The basement plan or foundation layout, Fig. 321, must be completely dimensioned because the house is started with this plan. It should be checked with the first-floor plan and may be traced from it. Note the foundations for the chimney, porches, etc., and other details. Windows should be under the first-floor windows.

208. Plot Plan.—This is a plan of the site showing the location of the house and accessory buildings on the lot. It should give complete and accurate dimensions, indicate all driveways, walks, show the location of electric, gas, water, sewer and telephone lines and should give all other pertinent information. A plot plan is shown as a part of Fig. 321.

209. Elevations.—A front elevation is shown in Fig. 322 and a side elevation in Fig. 323. Four elevations (front, back and both sides) are included in a complete set of plans and are required for Federal Housing Administration (F.H.A.) loans. The elevations show the exterior appearance of the house, floor and ceiling heights, openings for windows and doors, roof pitch, etc. To draw an elevation, start with the grade line, locate the floor levels and the vertical dimensions of other features. Horizontal dimensions can be obtained by placing a plan above the elevation or underneath if tracing paper is used.

210. Details.—A wall section to a larger scale is shown at the left in Fig. 323. Other larger scale drawings are made of such parts as cannot be shown with sufficient detail on the quarter-inch scale drawings. A typical sheet of such details is shown in Fig. 324. As the building progresses, the architect furnishes full-size drawings made with a soft pencil, for millwork, moldings, and any special details.

CHAPTER XVII

STRUCTURAL DRAFTING

211. Structural drafting has to do with the drawings made for the framework and supporting members of structures, such as columns, floor members, roof trusses and bridge trusses.

The picture of a part of a flat steel truss for a building is presented in Fig. 325. It has been made up or "fabricated" in the shop, and as shown it is ready for shipment to the site of the building. The top horizontal member or "top chord" is made of

Fig. 325.—Riveted joints in steel construction.

two "angles" (see Fig. 327). The "bottom chord" is made of smaller angles. The "diagonals" are made of single angles. Notice how the various members are connected by riveting to steel "gusset plates." The design of structures requires a knowledge of the many subjects included in structural engineering, such as mathematics, stresses, mechanics, properties of materials, methods of fabricating and methods of erection. However, the student should know some of the characteristics of drawings made for such purposes and how they differ from other drawings.

212. Structural Drawings.—Assembly or part-assembly working drawings form a large class of structural drawings. These include the "skeleton" or basic and center lines to locate the "working points," the structural members, gage lines, location dimensions, notes and other necessary information. Such a general working drawing is shown in Fig. 320 for a small steel roof truss. Since the truss is symmetrical about a vertical center line, it is necessary to show only one-half of it in the drawing.

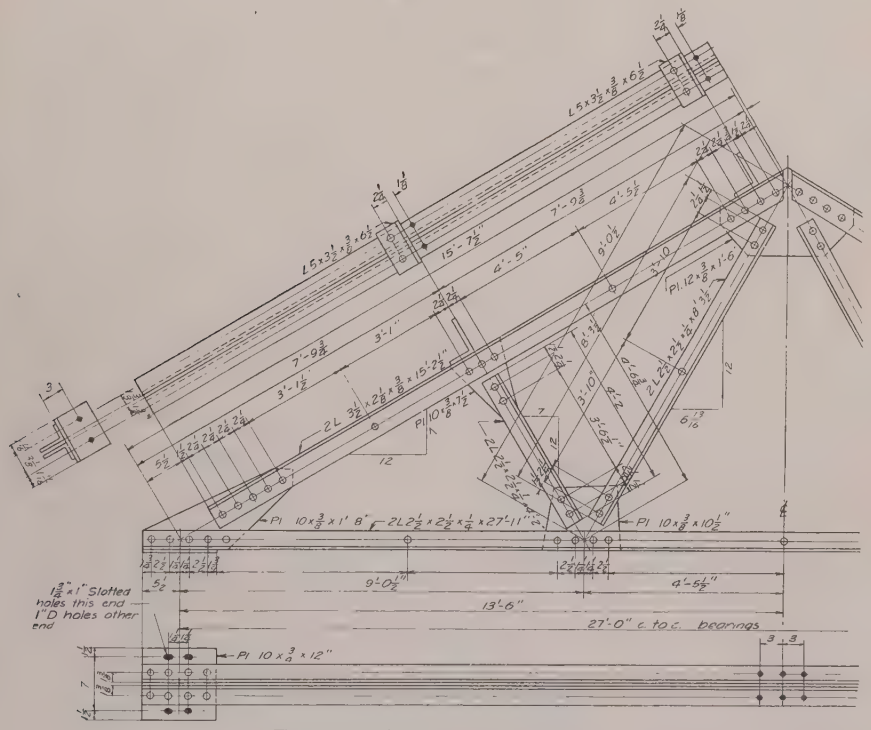


FIG. 326.—A structural drawing.

Notice the line upon which the design is built and the notes used to designate the various features. The sizes of the gusset plates are given in notes as are the number and sizes of angles (Ls). The slope or inclination is indicated by a right triangle, one leg of which is 12″. A study of the drawing will show that each member is completely dimensioned or described and that dimensions are given to fix the location of each member.

Separate shop drawings are made for complicated or special details and for repeated details.

213. Structural Shapes.—Structural members are built up of standard rolled shapes, some of which are shown in section in Fig. 327. Such shapes are made in a great variety of sizes and weights, lists of which may be found in the handbook, "Steel Construction," published by the American Institute of Steel Construction, or in the handbooks published by the various steel companies. The A.I.S.C. handbook contains tables of the properties of the various shapes and of many combinations of shapes, beam and column data, details of standard beam connections, specifications

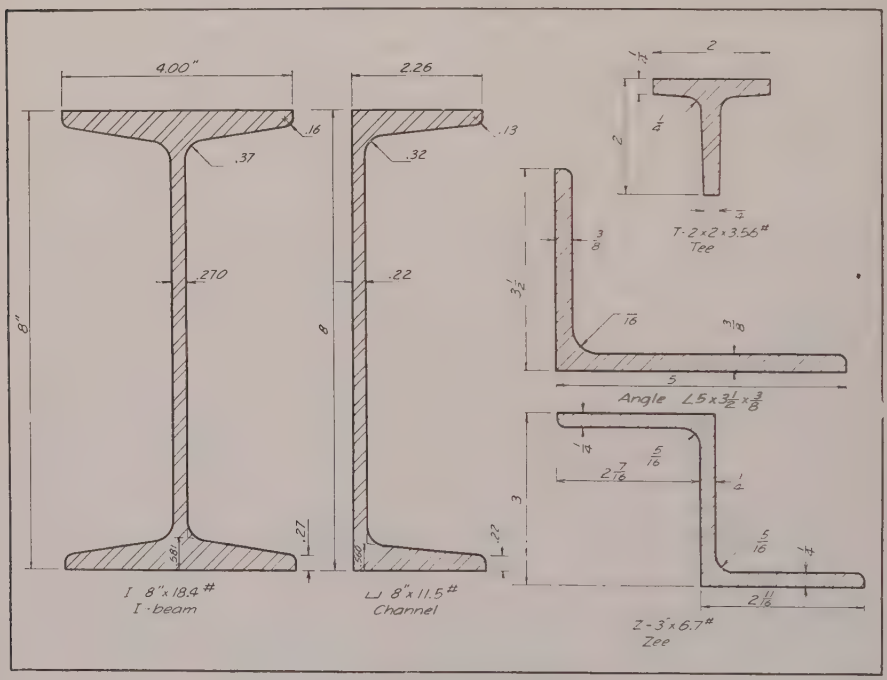


Fig. 327.—Rolled steel shapes.

for the design, fabrication and erection of structural steel for buildings, and a large amount of related information. Dimensions of steel plates are specified by giving the width, thickness and length; thus: Pl. 12 × ⅜ × 24. Angles are specified by dimensions, as the length of the legs and thickness of material; thus: ∟5 × 3½ × ⅜. Other shapes are specified by the main dimension and weight per foot:

18 WF 64 means 18″ wide flange I-beam, 64 lb. per foot.

Bar 2 ▫ means 2″ square bar.

Bar 1 ϕ means 1″ diameter round bar.

214. Detail Drawings.—Shop detail drawings give all the dimensions and information necessary to fabricate (or make) the parts. The location and kind of rivets is shown with everything drawn to scale. The simple beam detail of Fig. 328 shows the general characteristics of such drawings. Notice that the dimensions are placed above the dimension lines. The lower view is a section and on structural drawings is shown as seen from above.

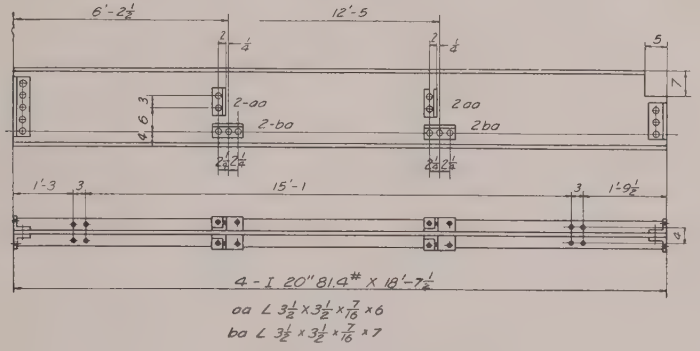


Fig. 328.—Structural detail.

The connections or angles at the ends of the beam are "Standard Beam Connections," and it is not necessary to dimension them. At the left end a "B5" connection is used, and at the right end, a "B3" connection; for the sizes of angles and dimensions, see a steel handbook (the rivets are ¾" diameter).

215. Reinforced Concrete.—Drawings made for reinforced concrete structures show the dimensions of the concrete members, sections, and give the sizes and locations of the steel reinforcing

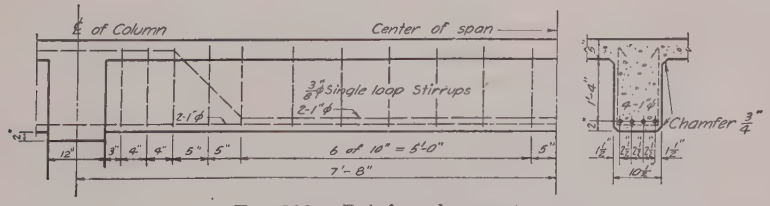


Fig. 329.—Reinforced concrete.

material. A part of such a drawing is shown in Fig. 329. Notice the symbol for the diameter of the steel rods and the representation of the rods by long dashes and blacked-in circles. The rods are drawn as though on different levels on the elevation in order to show how two of the rods are bent. The section shows them on the same level along the bottom of the beam. The symbol for concrete is shown in Fig. 147. Reinforced concrete design

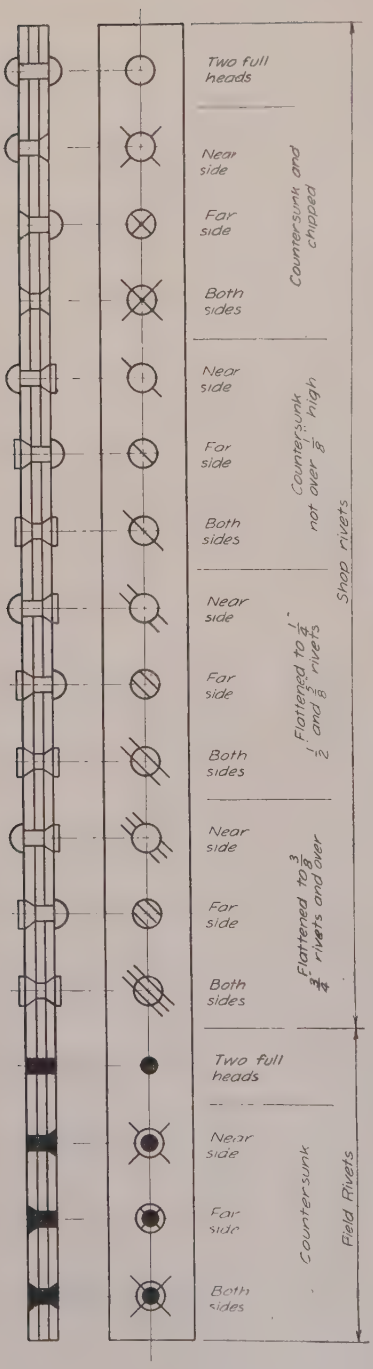


FIG. 330.—Rivet symbols.

requires a good knowledge of mathematics, mechanics and materials and is a specialized field of structural engineering.

The proportions of the materials to be used to give the required strength must be understood—the amounts of cement, sand, gravel or crushed rock, and water—as well as the computation of the size and amount of steel and the placing of the steel.

Many interesting applications of reinforced concrete construction can be found in the pages of *Engineering News* and similar magazines—such as dams, retaining walls, bridges, walls, beams and floors of buildings and roads.

216. Riveting.—Structural rivets are shown in Fig. 180. The Standard symbols for riveting are given in Fig. 330. Riveting done in the shop is called "shop riveting," whereas that done in the field where the work is being erected is called "field riveting" (shown in black on drawings). Lines on which rivets are spaced are called "gage lines," and the distance between centers along these lines is called the "pitch." Welding (Art. 108) is increasing in use for fabricating structural steel shapes.

Many buildings of steel construction are welded throughout. Others are partly welded and partly riveted.

Sometimes steel construction is put together by bolting, especially in locations which are remote from facilities for welding or riveting.

CHAPTER XVIII

MAP DRAFTING

217. Maps are essentially one-view drawings of parts of the earth's surface. There are so many features to be represented and so many uses for maps that they are made in a great variety of classes. Some maps, such as city plats, must be extremely accurate and made to a relatively large scale (50 to 200 feet to the inch), whereas geographic maps of states or countries, which show boundary lines, streams, lakes, coast line and relative locations,

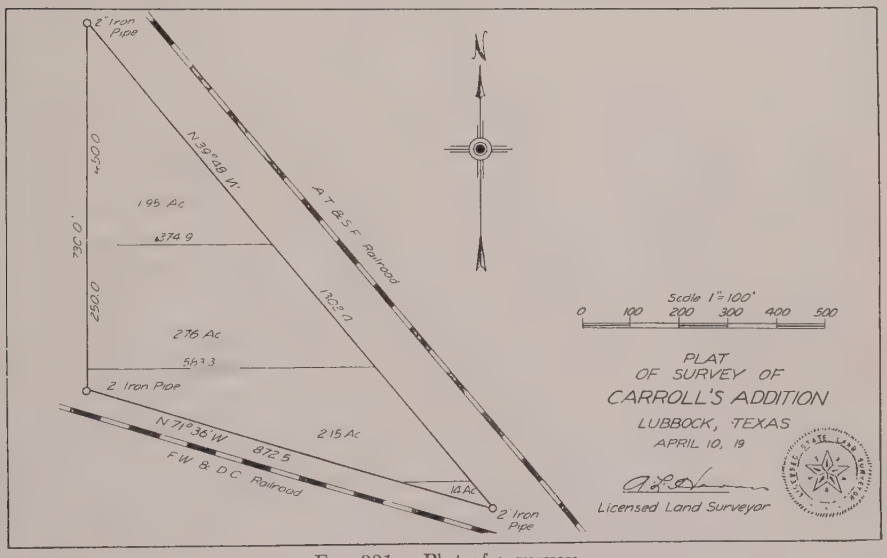


FIG. 331.—Plat of a survey.

may use a scale of several miles to the inch (see the maps in your geography and history books).

218. Plats of a Survey.—A map to record the boundaries of a tract of land and to identify it is called a "plat." The amount and kind of information will depend upon the purpose for which the map is required. The plat of a plane survey is shown in Fig. 331 which was made to record the legal description of the property.

219. City Plat. –Maps of cities are made for many purposes, such as to maintain a record of street improvements, location of

utilities and sizes and location of property for tax assessments. A part of such a city plat is shown in Fig. 332. Notice the numbering of the lots, location of streets and alleys, sidewalks, etc.

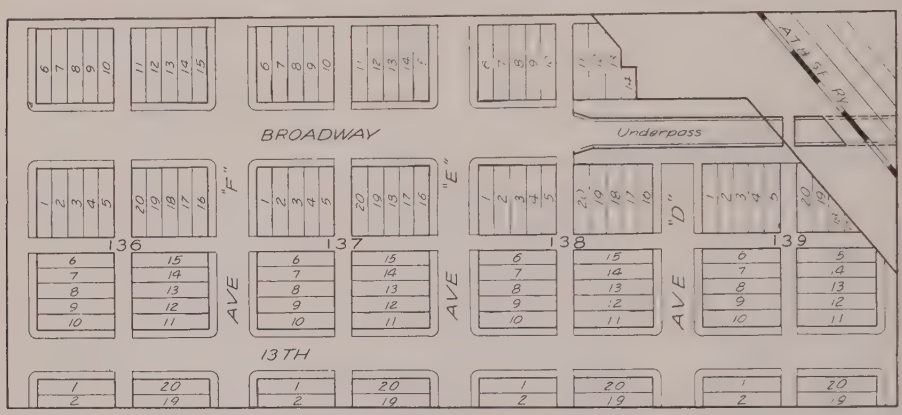


Fig. 332.—City map.

220. Contours.—Since maps are one-view drawings, vertical distances or variation in ground levels do not show. They can, however, be indicated by lines of constant level called "contours."

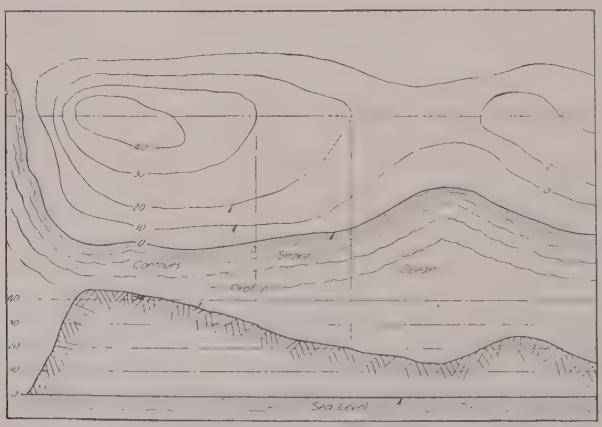


Fig. 333.—Contours.

This is illustrated in Fig. 333 where the contours show the location of lines on the ground which are at stated heights above the ocean (sea level). Contour lines close together indicate a steeper slope than lines further apart, as can be seen by projecting up the intersections of the horizontal level lines with the profile section of Fig. 333 as indicated.

It will be observed that the contour map and the profile correspond to the plan and section of an ordinary drawing. Note the horizontal line or cutting plane on the contour map, which shows the position or line on which the profile is taken. Notice how the profile would change if the cutting plane was moved toward the ocean or to some other new position.

221. A contour map is shown in Fig. 334 with contour intervals of 50 feet (distance between contour levels). When there are

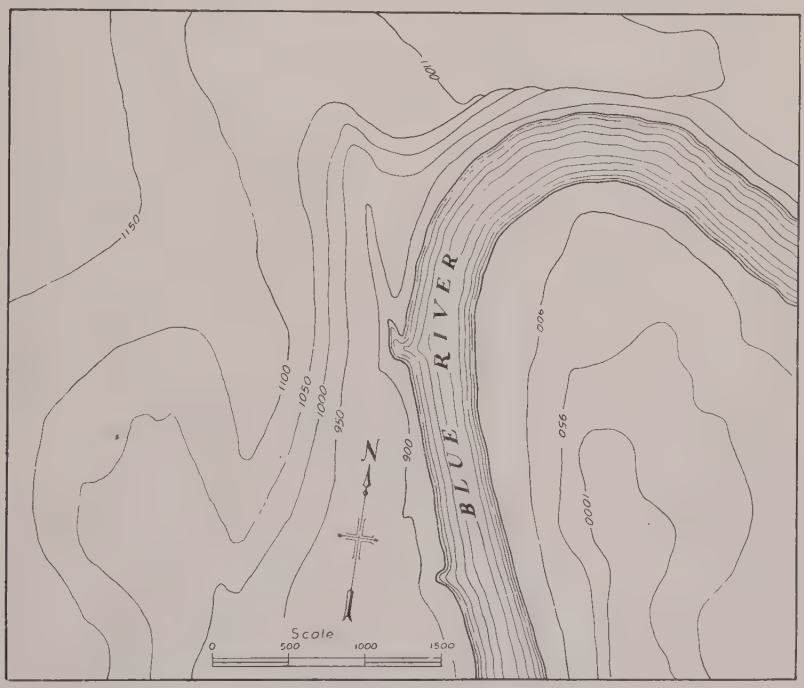


FIG. 334.—Contour map.

many contour lines, every fifth one is drawn heavier to make them easier to follow. The elevation in feet is marked in a break in the line. Notice the "water lining" used on the representation of the river.

222. Topographic Maps are made to give rather complete descriptions of the areas shown. This includes such information as boundaries, natural features, the works of man, vegetation and relief (elevations and depressions). Symbols are used for many of the features shown on topographic maps, some of which are given in Fig. 335. Maps using topographic symbols can be obtained at nominal cost from the Director, U.S. Geological

Survey, Department of the Interior, Washington, D.C., and represent the highest type of topographic drawing.

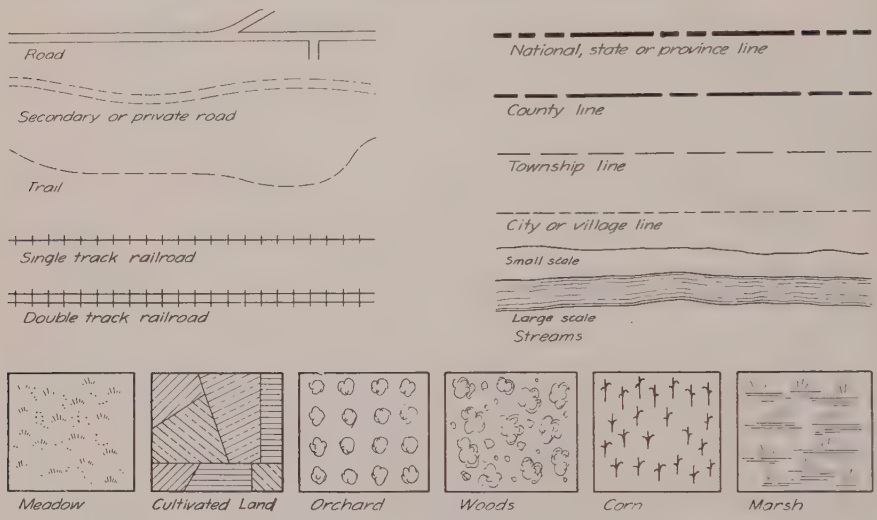


Fig. 335.—Conventional symbols.

The making of maps is an important part of civil engineering and requires thorough training. Books on surveying and mapping and U.S. government bulletins should be studied before undertaking work on any important maps.

CHAPTER XIX

PROBLEMS

Groups		Page
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223. The important part of any course in mechanical drawing consists of the working of a large number of properly selected and graded problems. The problems which follow are arranged somewhat in the order of difficulty in each of the divisions of the subject, and the methods of presentation are varied to suit the objectives and requirements of the problems. Graphic layouts are given when practicable, as they are definite and save time for both teacher and pupil. It is not necessary or intended that all the problems be worked; a selection to fit the course will be made by the teacher. A large number of references to text matter are given with the problems and should be studied before asking for assistance from the teacher.

Any or all of the drawings may be inked but the best results are generally obtained by delaying this until the pupil has acquired the ability to make a good pencil drawing.

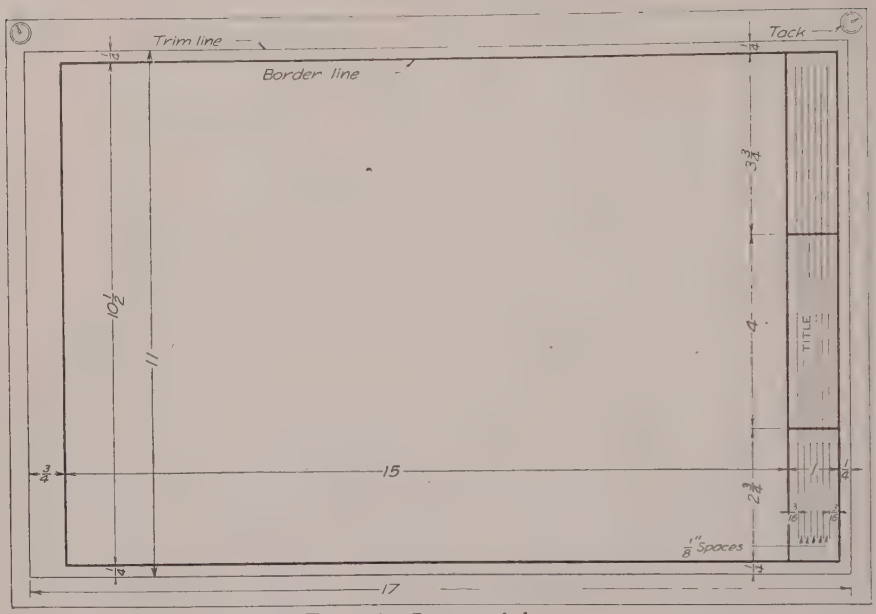


Fig. 336.—Layout of sheet.

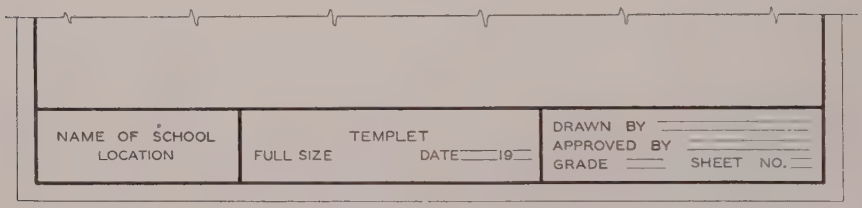


Fig. 337.—Record strip.

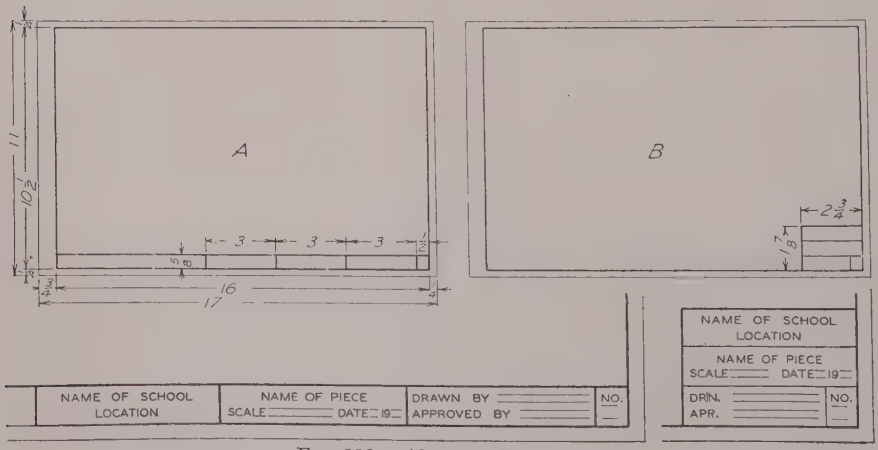


Fig. 338.—Alternate layouts.

The problems are designed for use on the size of sheet and layout given in Figs. 336 and 337, but it is, of course, easily possible to use other sizes or arrangements as suggested in Fig. 338.

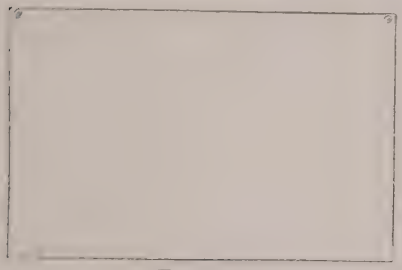


FIG. 339.

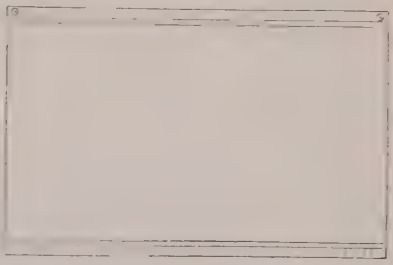


FIG. 340.

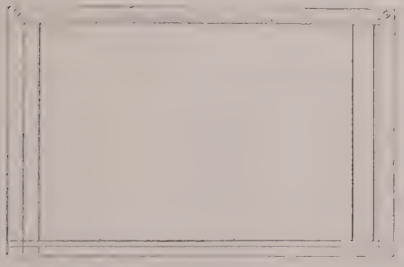


FIG. 341.

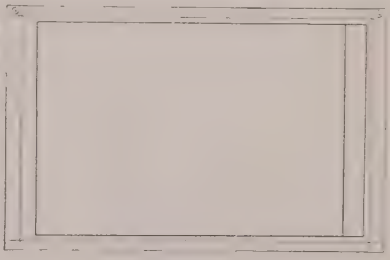


FIG. 342.

224. Layout of the Sheet.—Read Arts. 5 to 8. Tack the paper to the board as described in Art. 6. The outside dimensions to which the finished sheet will be trimmed are 11″ × 17″, with border line and record strip as shown in Fig. 336. (The guide lines for lettering in the record strip, Fig. 337, are not to be put in until the drawing is finished ready for the title.) By following the method illustrated in progressive steps, the layout of a sheet should not take more than two minutes.

The Two-minute Method. With the scale measure 17″ near the bottom of the sheet, making short vertical marks, not dots. Measure and mark ¾″ in from the left-hand mark and ¼″ in from the right-hand mark (Fig. 339). From this last mark measure 1″ toward the left and mark. Lay the scale vertically near the left of the paper and make short horizontal marks 11″ apart. Make short marks ¼″ down from the top mark and ¼″ up from the bottom mark. Now with the T-square draw horizontal lines through the four marks last made (Fig. 340). Next draw vertical lines through the five vertical marks (Fig. 341). Then brighten up the border lines and the sheet will appear as in Fig. 342, ready to begin a drawing.

225. General Instructions.—On the following problems the figures enclosed in circles are for locating the starting lines and are always measured full size regardless of the scale of the views of the drawing. When such dimensions are given, the lines which they locate should be drawn first. (These dimensions should not be put on the completed drawing.) Upon these lines the drawing is built. Use light, sharp pencil lines and work very accurately, as errors in starting often are not evident until the drawing is nearly completed. The title for each sheet is given in **black-face** type.

Group I. Use of Instruments.

Prob. 1. The first sheet (Fig. 343) is a one-view drawing of a **templet.** Complete specifications would require that the thickness and kind of material be given.

In this and the following one-view problems the order of making the drawing is shown in progressive stages. These stages should be followed carefully as they represent the draftsman's practice as to procedure in making drawings.

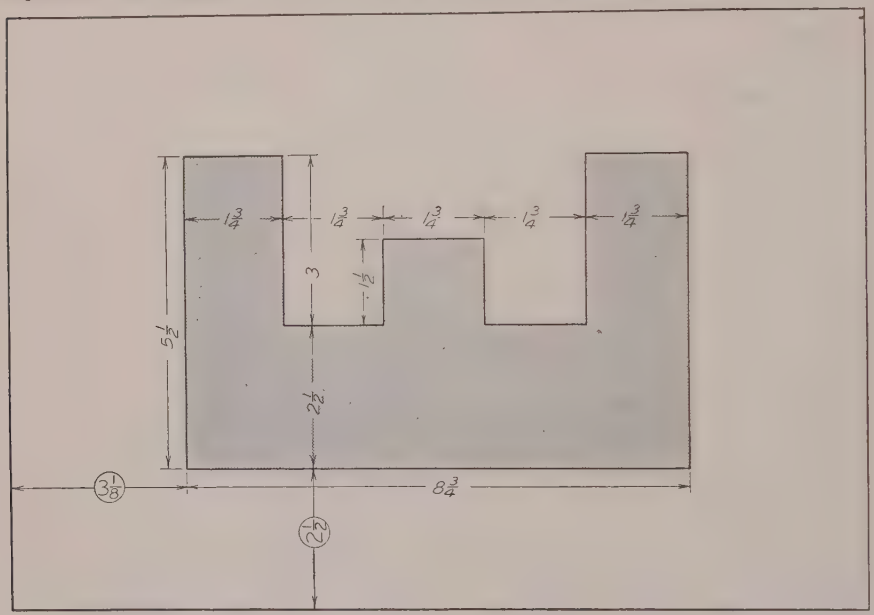


FIG. 343.—Prob. 1. Templet.

It is necessary for the beginner to learn to draw in *good form*, and the most important feature in this regard is the order of working. Do not simply follow the explanations as being directions for the particular problem, but try to understand the system and the reasons for it. This system, thoroughly mastered at the start, will apply to all drawings regardless of the number or complexity of views and will develop the two requirements in execution: *accuracy* and *speed*.

Order of Working.

1. Lay out the sheet as described on the preceding page.

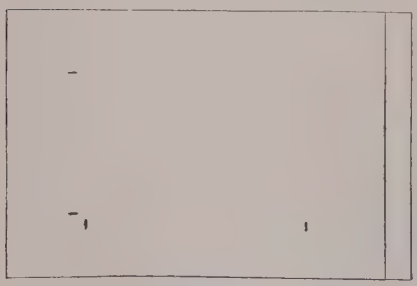


FIG. 344.

2. Measure $3\frac{1}{8}''$ from left border line and from this mark measure $8\frac{3}{4}''$ toward the right.

3. Lay the scale on the paper vertically near the left edge, make a mark $2\frac{1}{2}''$ up and from this measure $5\frac{1}{2}''$ more. The sheet will appear as in Fig. 344.

4. Draw horizontal lines 1 and 2 with the T-square, and vertical lines 3 and 4 with T-square and triangle (Fig.

345), being careful to hold the instruments as illustrated in Fig. 8. These four lines "block in" the figure.

5. Lay the scale along the bottom line of the figure with the measuring edge on the upper side and make marks $1\frac{3}{4}''$ apart. Then with the scale on line 3,

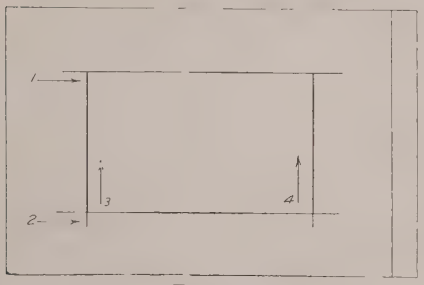


Fig. 345.

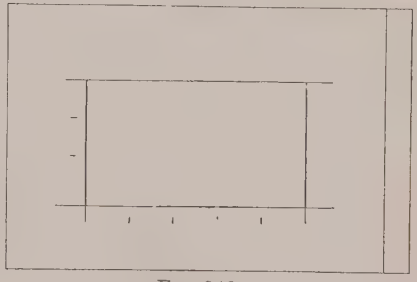


Fig. 346.

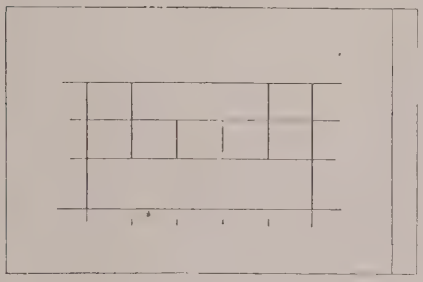


Fig. 347.

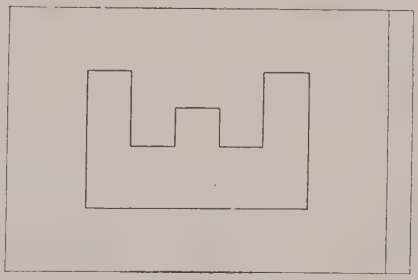


Fig. 348.

with its measuring edge to the left, measure from the bottom line two successive distances vertically, $2\frac{1}{2}''$ and $1\frac{1}{2}''$. The sheet will now appear as in Fig. 346.

6. Through the two marks just made draw two horizontal lines lightly across the figure.

7. Draw the vertical lines with T-square and triangle, setting the pencil on the marks on the bottom line and starting and stopping the lines on the proper horizontal lines (Fig. 347).

8. Erase the lines not wanted and brighten the lines of the figure to obtain the finished drawing (Fig. 348).

9. Write your name, sheet number and date lightly in the record strip. The record strip is to be lettered in later after sufficient practice in lettering.

10. Trim sheet to finished size.

Prob. 2. Figure 349 is an alternate problem, using the same measurements, for a **gage.**

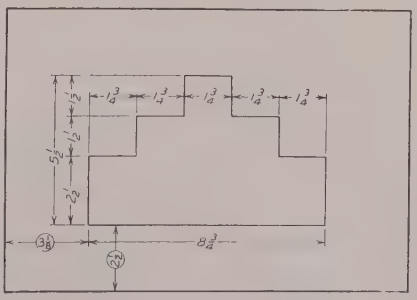


Fig. 349.—Prob. 2. Gage.

Prob. 3. To make a drawing of the **stencil** (Fig. 350). This drawing gives practice in accurate measuring with the scale and making careful corners with short lines. The construction lines shown in Figs. 351, 352 and 353 should be drawn very lightly and with a well sharpened pencil. All measurements must be made very carefully and accurately.

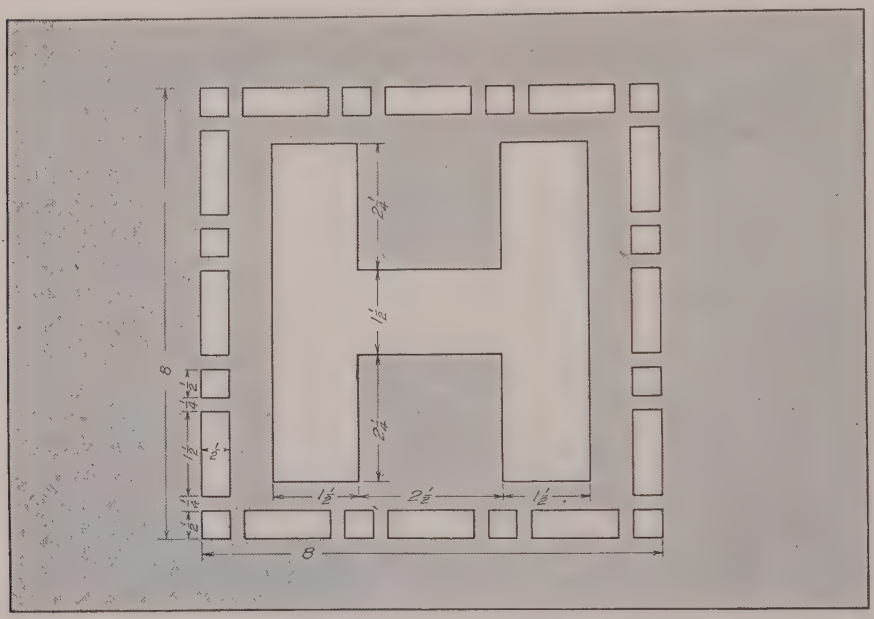


Fig. 350.—Prob. 3. Stencil.

Order of Working.

1. Find the center of the sheet inside the border by laying the T-square blade face down across the corners and drawing short pieces of the diagonals where they intersect (Fig. 351).

2. Through the center draw a horizontal center line and on it measure and mark off points for the four vertical lines (Fig. 352).

3. Draw the vertical lines lightly with T-square and triangle. On the first one measure and mark off points for all horizontal lines (Fig. 353).

4. Draw the horizontal lines as finished lines, and measure points for the stencil border lines on the left side and bottom, as shown in Fig. 354.

5. Draw the border lines and measure on them the points for the ties (Fig. 355).

6. Complete the border by drawing the cross lines as finished lines and brightening the other lines (Fig. 356).

7. Brighten the vertical lines and finish as in Fig. 357.

8. Write name, sheet number and date in the record strip and trim the sheet to finished size.

Prob. 4. To make a drawing of the **tile pattern** (Fig. 358). This is an alternate problem, using the same measurements as in Fig. 350 with additional $1\frac{1}{2}''$ measurements for the top and bottom strips and for the middle vertical strip.

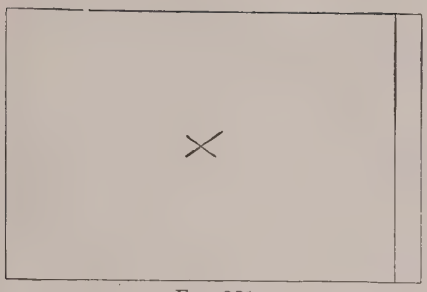


FIG. 351.

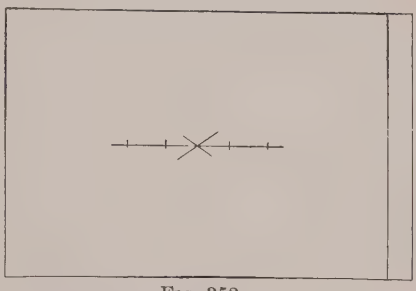


FIG. 352.

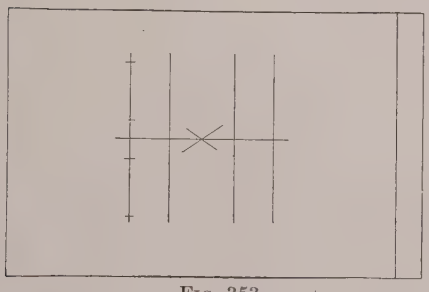


FIG. 353.

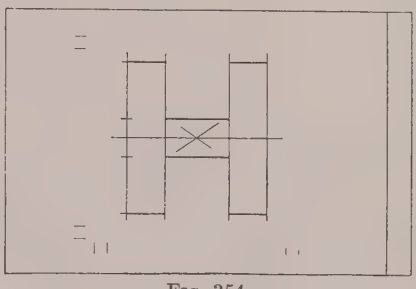


FIG. 354.

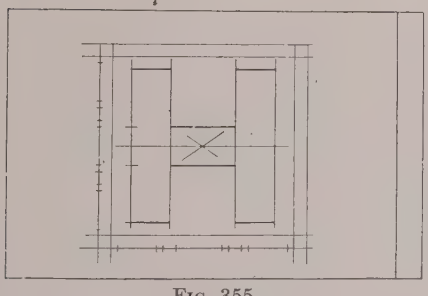


FIG. 355.

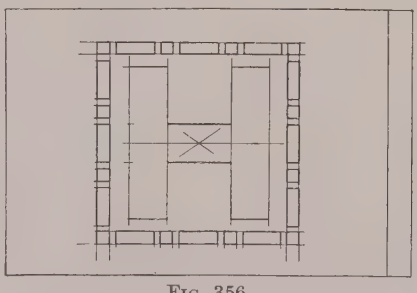


FIG. 356.

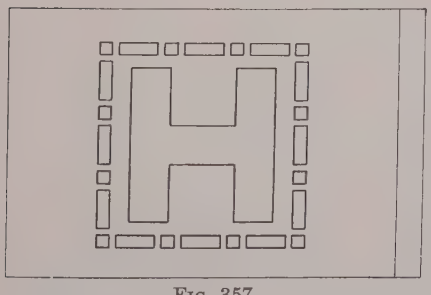


FIG. 357.

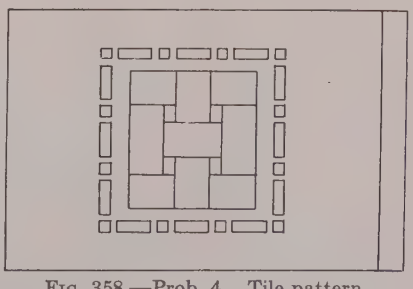


FIG. 358.—Prob. 4. Tile pattern.

Prob. 5. To make a drawing of the **shim** (Fig. 359). For practice with compasses. Read Art. 11. When circles and circle arcs occur on a drawing, the first step is to locate the centers, the second to mark off the radii, the third to locate the points of tangency and make sure of smooth joints.

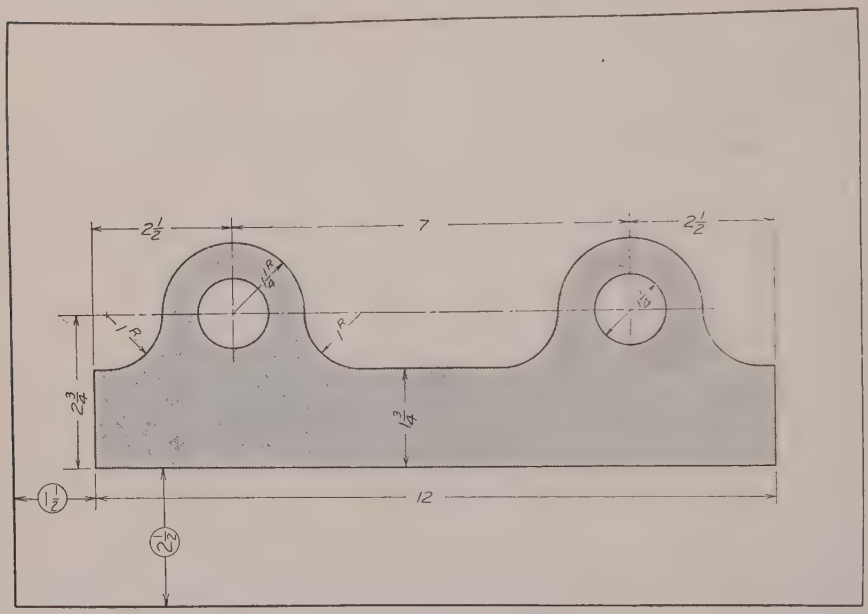


Fig. 359.—Prob. 5. Shim.

Be sure that the lead in the compasses is carefully sharpened and adjusted with the needle point as shown in Fig. 13. Draw intersecting center lines on a separate sheet, and practice handling both the compasses and bow pencil in drawing circles, carefully observing the operations illustrated in Figs. 14 and 15. The needle point may be placed at the exact crossing of the two center lines by guiding it with the little finger of the left hand, resting the other fingers on the paper.

Tangents occur constantly on all machine drawings and must be drawn neatly and quickly. Accuracy in setting the compasses to a required radius should be practiced, as any error is doubled when the diameter is measured.

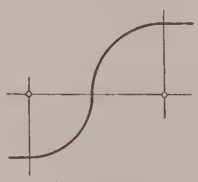


Fig. 359*a*.

Note that when two circle arcs are tangent to each other the point of tangency must lie on a line joining the centers of the arcs (Fig. 359*a*).

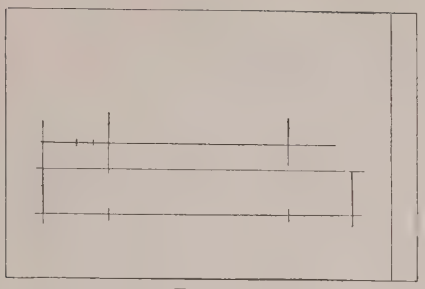


FIG. 360.

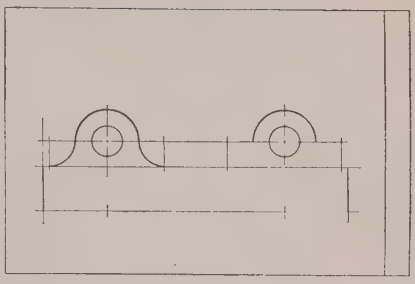


FIG. 361.

Order of Working.

1. Draw the base line $2\frac{1}{2}''$ from the bottom. On it measure in $1\frac{1}{2}''$ from the left border, then the distances $2\frac{1}{2}''$, $7''$ and $2\frac{1}{2}''$ (Fig. 360).

2. Measure the vertical distances $1\frac{3}{4}''$ and $2\frac{3}{4}''$ (Fig. 360).

3. Draw the horizontal lines, then the vertical lines (Fig. 360).

4. On the horizontal center line mark points for the radii and draw the two circles, then the two semicircles, then the fillets. Be sure to stop at the tangent points (Fig. 361).

5. Brighten the lines of the figures, leaving the center lines lighter than the outlines, as in Fig. 362.

6. Write name, sheet number and date lightly in the record strip, and trim the sheet.

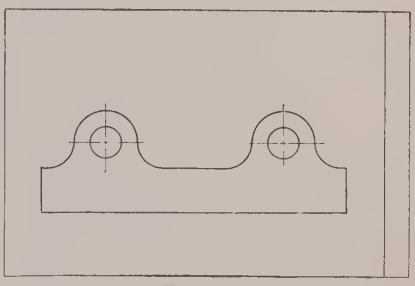


FIG. 362.

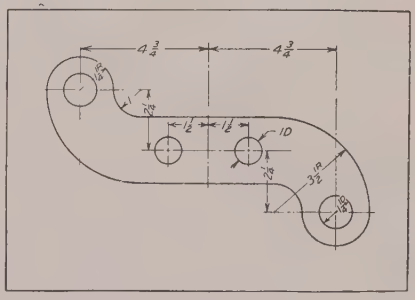


FIG. 363.—Prob. 6. Brace.

Prob. 6. To make a drawing of a **brace** (Fig. 363). Plan a systematic order of working before starting the drawing.

Prob. 7. To make a drawing of a **T-square head** (Fig. 364). Plan a systematic order of working before starting the drawing.

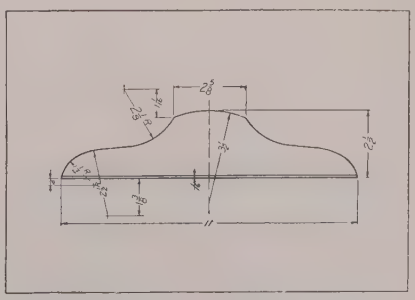


FIG. 364.—Prob. 7. T-square head.

Prob. 8. To make a drawing of the **shearing blank** (Fig. 365). When a view has inclined lines, it should first be "blocked in" with square corners. Angles of 15°, 30°, 45°, 60° and 75° are drawn with the triangles after locating one end of the line. See Fig. 10.

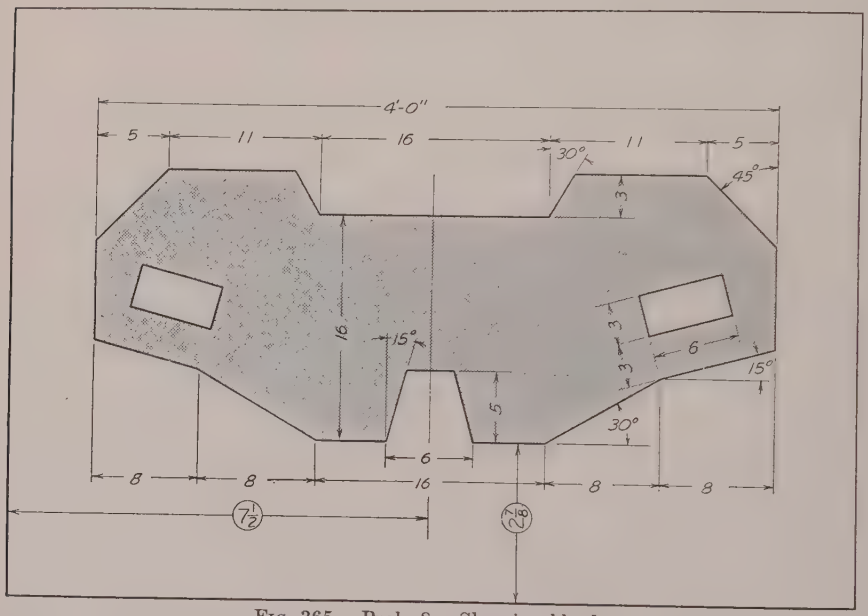


FIG. 365.—Prob. 8. Shearing blank.

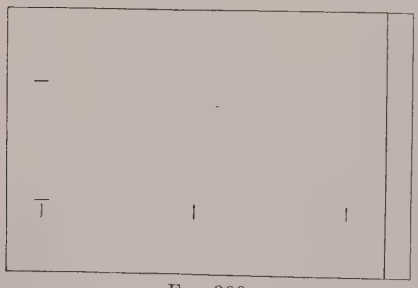


FIG. 366.

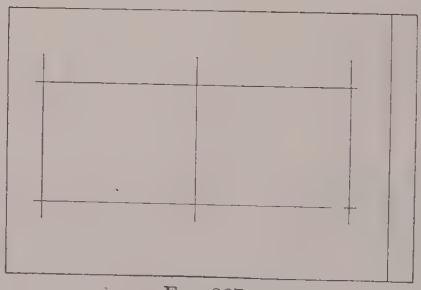


FIG. 367.

Order of Working.

1. Locate vertical center line and measure two feet on each side (Fig. 366). Note that this drawing must be made to the scale of 3″ = 1′ (Art. 14).

2. Locate vertical distances for top and bottom lines.

3. Draw main "blocking-in" lines as in Fig. 367.

4. Make measurements for starting points of inclined lines (Fig. 368).

5. Draw inclined lines with T-square and triangles (Fig. 369).

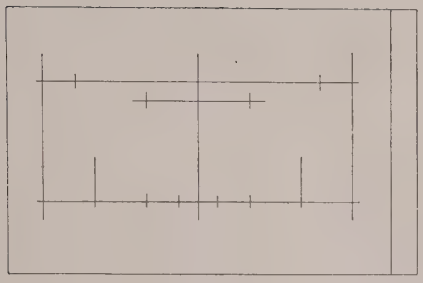


FIG. 368.

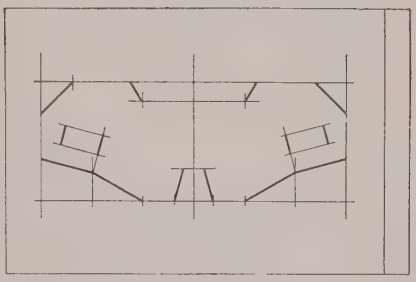


FIG. 369.

6. Finish as in Fig. 370.

7. Write name, sheet number and date in record strip, and trim to size.

Prob. 9. To draw an **inlaid table top** (Fig. 371). Draw horizontal and vertical center lines. Plan a systematic order of working. The central inlay may be varied, using one of the suggestions of Fig. 372 or the student's own original design.

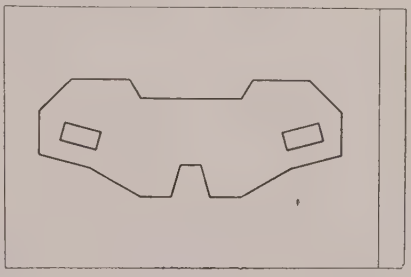


FIG. 370

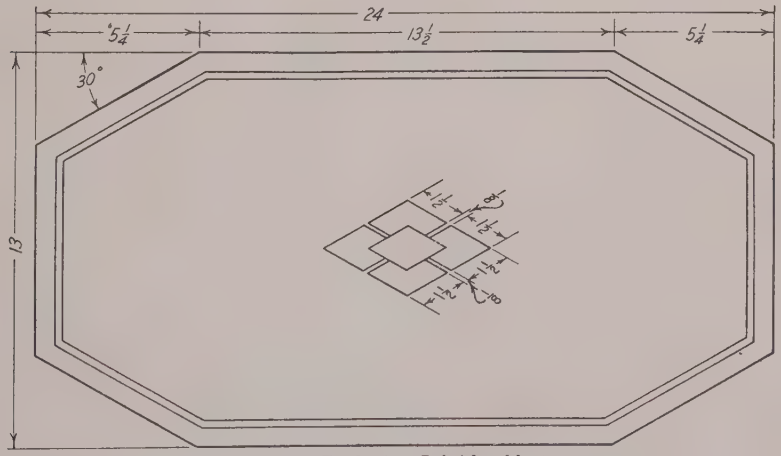


FIG. 371.—Prob. 9. Inlaid table top.

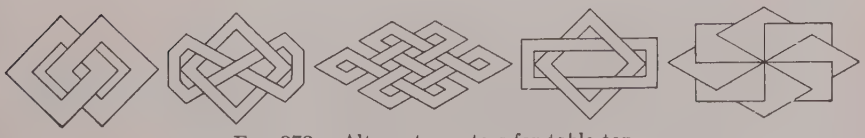


FIG. 372.—Alternate centers for table top.

Prob. 10. To make a drawing of the **cushioning base** (Fig. 373). For practice with triangles, compasses and scale. Centers of arcs and tangent points must be carefully located.

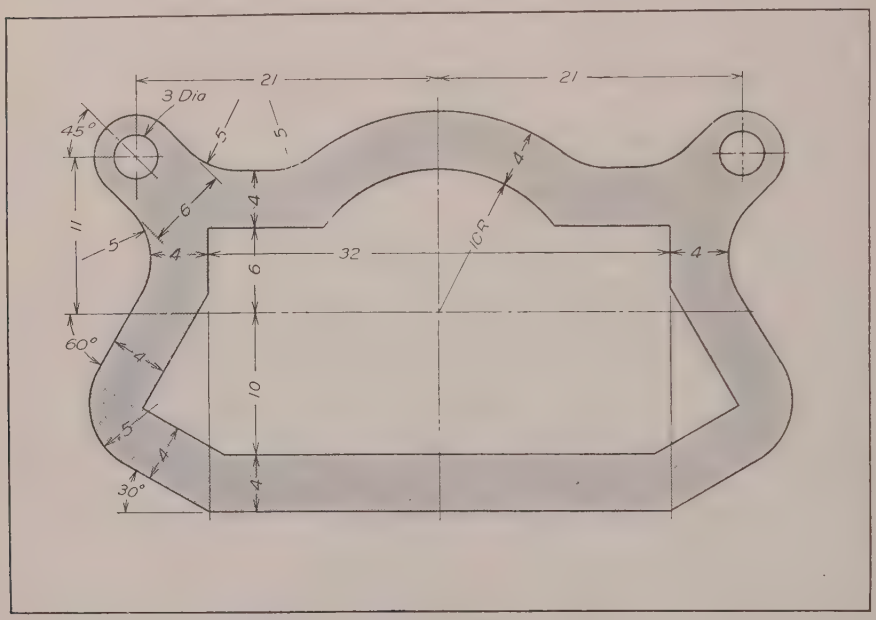


Fig. 373.—Prob. 10. Cushioning base.

Order of Working.

1. Through the center of the working space draw horizontal and vertical center lines. Measure horizontal and vertical distances. This drawing must be made to the scale of 3″ = 1′. Then draw horizontal and vertical lines (Fig. 374).

2. Draw inclined lines with 45° and 30°–60° triangles. Then draw large arcs and two semi-circles with tangents at 45° (Fig. 375).

3. Locate centers and tangent points for the 5″ radius tangent arcs. To do this, measure 5″ perpendicularly from each tangent line and draw lines parallel to the tangent lines. The intersection of these lines will be the required centers. To find the points of tangency, draw lines from the centers perpendicular to the tangent lines. To find the centers for the 5″ arcs tangent to the middle arc, proceed as follows: Increase the radius of the larger arc by 5″ and draw two short arcs cutting lines parallel to and 5″ above the top horizontal tangent line. These points will be the centers. Lines joining these centers with the center of the large arc will locate the points of tangency of the arcs (Fig. 376).

Draw all the 5″ tangent arcs above the horizontal center line. Locate points of tangency and draw the two 60° tangent lines. Locate centers and draw the 5″ tangent arcs below the center line.

4. Complete the view by drawing the lines for the opening. Brighten the lines and finish (Fig. 377).

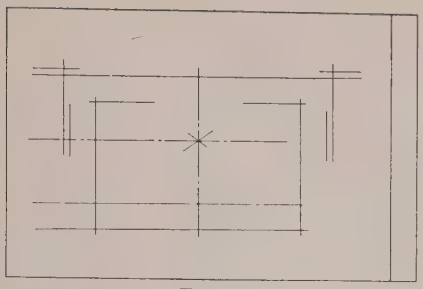


FIG. 374.

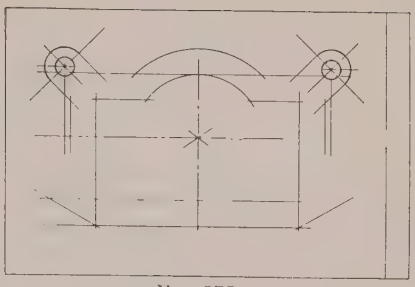


FIG. 375.

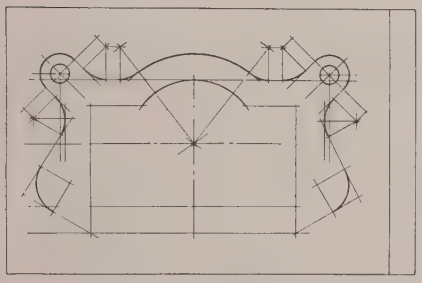


FIG. 376.

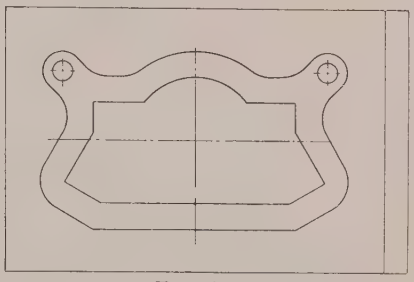


FIG. 377.

Group II. Geometrical Constructions.

226. The working of a limited number of geometrical exercises is valuable both for the practice in the use of instruments and for the gaining of familiarity with the constructions which occur most frequently in drafting. Such problems must be worked very accurately, with a very sharp pencil and comparatively light lines. A point should be located by two intersecting lines and the length of a line by two short dashes crossing the given line.

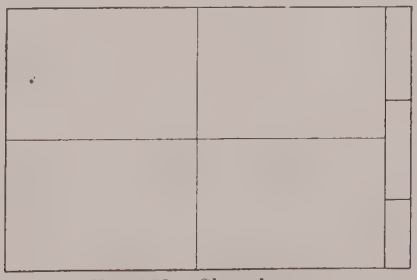


FIG. 378.—Sheet layout.

The following problems are designed to be drawn in one-quarter of the working space of an $11'' \times 17''$ sheet. Lay out the sheet as in Fig. 336 and draw horizontal and vertical lines to divide the space into four equal parts as shown in Fig. 378.

Prob. 11. Art. 150, page 121. Near the center of the space draw a line $3\frac{11}{16}''$ long and bisect it.

Prob. 12. Art. 150, page 121. Near the center of the space draw a line $3\frac{7}{16}''$ long and bisect it.

Prob. 13. Art. 151, page 121. Above the center of the space draw a horizontal line $5\frac{13}{16}''$ long. Divide it into seven equal parts geometrically.

Prob. 14. Art. 151, page 121. To the left of the center draw a vertical line $3\frac{7}{16}''$ long and divide it into five equal parts geometrically.

Prob. 15. Art. 154, page 122. Locate a point $\frac{3}{4}''$ above lower line of space and 1″ from left side. Draw lines joining the middle points of the upper and right-hand sides of the space. Bisect the angle between these lines.

Prob. 16. Art. 154, page 122. Locate a point $\frac{3}{4}''$ below the middle of the upper line of the space. Draw lines joining this point with the lower right-hand corner and with the middle of left side of space. Bisect the angle between these lines.

Prob. 17. Art. 155, page 123. Draw a vertical line $\frac{3}{4}''$ from left edge of space. From a point on this line $\frac{3}{4}''$ below top of space draw another line making any angle. Copy this angle so that one side is $\frac{3}{4}''$ from right side of space and vertex is $\frac{3}{4}''$ from bottom of space.

Prob. 18. Art. 155, page 123. From the middle of left side of space draw lines to upper and lower right-hand corners. Copy this angle so that one side is horizontal and $\frac{1}{2}''$ above bottom of space.

Prob. 19. Art. 156, page 123. Draw a horizontal line $4\frac{3}{4}''$ long and 1″ above bottom of space. On it as a base construct a triangle having sides of $4\frac{1}{8}''$ and $3\frac{1}{4}''$.

Prob. 20. Art. 156, page 123. Draw a vertical line $2\frac{7}{8}''$ long and $1\frac{1}{2}''$ from left side of space. On it construct a triangle having sides of $5\frac{1}{8}''$ and $4\frac{3}{4}''$.

Prob. 21. Art. 156, page 123. Draw a horizontal line $4\frac{1}{2}''$ long and 1″ above bottom of space. Using this as the longer of two sides, construct a right triangle by the 6-8-10 method.

Prob. 22. Art. 157, page 124. Draw a regular pentagon in a circle whose diameter is $3\frac{3}{4}''$.

Prob. 23. Art. 158, page 124. Draw a regular hexagon $3\frac{3}{4}''$ across corners.

Prob. 24. Art. 159, page 124. Draw a regular octagon in a $3\frac{1}{2}''$ square.

Prob. 25. Art. 160, page 125. Locate three points as follows: point *A* $3\frac{3}{4}''$ from left edge of space and $4\frac{1}{4}''$ above bottom of space; *B* $5\frac{1}{4}''$ from left edge and $2\frac{5}{8}''$ from bottom; *C* 2″ from left edge and $1\frac{3}{4}''$ from bottom. Draw a circle through *A*, *B* and *C*.

Prob. 26. Art. 162, page 125. Locate a point $\frac{1}{2}''$ from bottom of space and $\frac{1}{2}''$ from left edge. Draw lines from this point to middle of top of space and to lower right-hand corner. Draw an arc tangent to these two lines with a radius of $1\frac{1}{2}''$.

Prob. 27. Art. 165, page 126. Draw an arc having a radius of $3\frac{1}{2}''$, with its center $\frac{3}{4}''$ from top of space and $1\frac{3}{4}''$ from left edge. Find the length of an arc of 60°.

Prob. 28. Art. 166, page 126. From the left edge of the space draw a horizontal line $1\frac{1}{2}''$ long and $1\frac{1}{4}''$ below top of space. From right edge draw a horizontal line $1\frac{1}{2}''$ long and $1\frac{1}{4}''$ above bottom of space. Join these two lines by an ogee curve. Point E to be one-third the distance from B to C (Fig. 268).

Prob. 29. Art. 167, page 126. Draw an equilateral triangle in the center of the space, sides $\frac{3}{4}''$ long. Draw one turn of an involute of the triangle.

Prob. 30. Art. 167, page 126. Locate a point $2\frac{3}{4}''$ below top of space and $2''$ from left side of space. With this point as a center draw a circle having a diameter of $3''$. Draw an involute of the right half of the circle.

Prob. 31. Art. 168, page 127. Draw horizontal and vertical lines through the center of the space. Draw one turn of a spiral of Archimedes in a $4''$ diameter circle.

Prob. 32. Art. 171, page 128. Draw an ellipse having a major axis of $4''$ and a minor axis of $2\frac{1}{2}''$. Use concentric-circle method.

Prob. 33. Art. 171, page 128. Draw an ellipse having a major axis of $4''$ and a minor axis of $1''$. Use concentric-circle method.

Prob. 34. Art. 172, page 129. Draw an approximate ellipse having a major axis of $4\frac{1}{2}''$ and a minor axis of $3\frac{1}{4}''$.

FIG. 379.—Prob. 35.

FIG. 380.—Prob. 36.

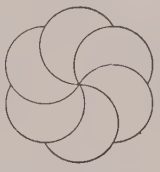


FIG. 381.—Prob. 37.

FIG. 382.—Prob. 40.

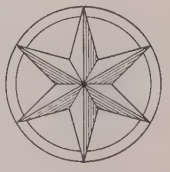


FIG. 383.—Prob. 41.

Prob. 35. Divide a $4''$ circle into 5 equal parts and draw a five-pointed star by connecting opposite points (Fig. 379).

Prob. 36. In a $4''$ circle draw interlaced triangles (Fig. 380). The bands are $\frac{1}{4}''$ wide.

Prob. 37. Draw a $4''$ circle. With six equally spaced radii as diameters draw circle arcs as in Fig. 381.

Prob. 38. Variation of Prob. 37 using 5, 8 or 12 radii.

Prob. 39. Variation of Prob. 37 or 38, adding a concentric-circle arc one-half the radius of first arc.

Prob. 40. In a $4''$ circle draw interlaced squares (Fig. 382), making the bands $\frac{1}{4}''$ wide.

Prob. 41. With 30°–60° and 45° triangles together draw the six-pointed star of Fig. 383. Refer to Fig. 10.

Group III. Lettering.

227. Lettering can best be taught using short practice periods. For such a purpose, lettering practice books, ready ruled and with directions, are available and are inexpensive. Book I, "Lessons in Lettering," by French and Turnbull is for vertical letters, and Book II is for inclined letters.

The exercises which follow can be done in one-quarter of the working space of a regular sheet (Fig. 378).

For pencil letters use a long conical point. Rotate the pencil in the fingers after each few strokes to keep the point symmetrical.

For ink letters use a penholder with a cork grip and set the pen well into the holder. Always use drawing ink for lettering. To get clean-cut letters, it is necessary to wipe the pen frequently with a cloth penwiper.

Problems are given for both vertical and inclined letters but only one kind should be taught beginners.

Vertical Lettering.

Probs. 42, 43, 44, 45. Fig. 384. Single-stroke vertical capitals in pencil. Layout sheet as in Fig. 378. Rule guide lines $\frac{3}{8}''$ apart, starting $\frac{1}{2}''$ over and $\frac{9}{16}''$ down. Letter as indicated in each space, making a careful study of the letters with the order and direction of the strokes as given in Fig. 28. Complete each line. Prob. 42, upper left-hand space. Prob. 43, upper right-hand space. Prob. 44, lower left-hand space. Prob. 45, lower right-hand space. Use an F pencil.

Prob. 46. Fig. 385 (upper left-hand space). Rule guide lines $\frac{3}{16}''$ apart, starting $1\frac{1}{4}''$ over and $1\frac{3}{16}''$ down. Make first two lines in pencil. Make next two lines very lightly in pencil and go over them with pen and ink. Use Gillott 404 pen. Make fifth and sixth lines in ink without first penciling. Seventh line in pencil. Eighth line in ink.

Prob. 47. Fig. 385 (upper right-hand space). Single-stroke vertical lower case in pencil. Rule guide lines as shown in lower left-hand space. Start $1\frac{1}{4}''$ over and $1\frac{3}{16}''$ down. The bodies of the letters are $\frac{1}{8}''$ high. The first space is $\frac{1}{16}''$ down, the next $\frac{1}{8}''$ and the next $\frac{3}{16}''$. Repeat until there are guide lines for eight lines of letters. Complete each line. Study Fig. 30.

Prob. 48. Fig. 385 (lower left-hand space). Same as Prob. 47, except that the lettering is to be done directly in ink.

Prob. 49. Fig. 385 (lower right-hand space). Rule as for Prob. 47. Letter the sentence first in pencil, then below, directly in ink.

Inclined Lettering.

Probs. 50, 51, 52, 53. Fig. 386. Single-stroke inclined capitals in pencil. Lay out sheet as in Fig. 378. Rule guide lines $\frac{3}{8}''$ apart, starting $\frac{1}{2}''$ over and $\frac{9}{16}''$ down. Letter as indicated in each space, making a careful study of the letters with the order and direction of strokes as given in Fig. 35. Complete each line. Prob. 50, upper left-hand space. Prob. 51, upper right-hand space. Prob. 52, lower left-hand space. Prob. 53, lower right-hand space.

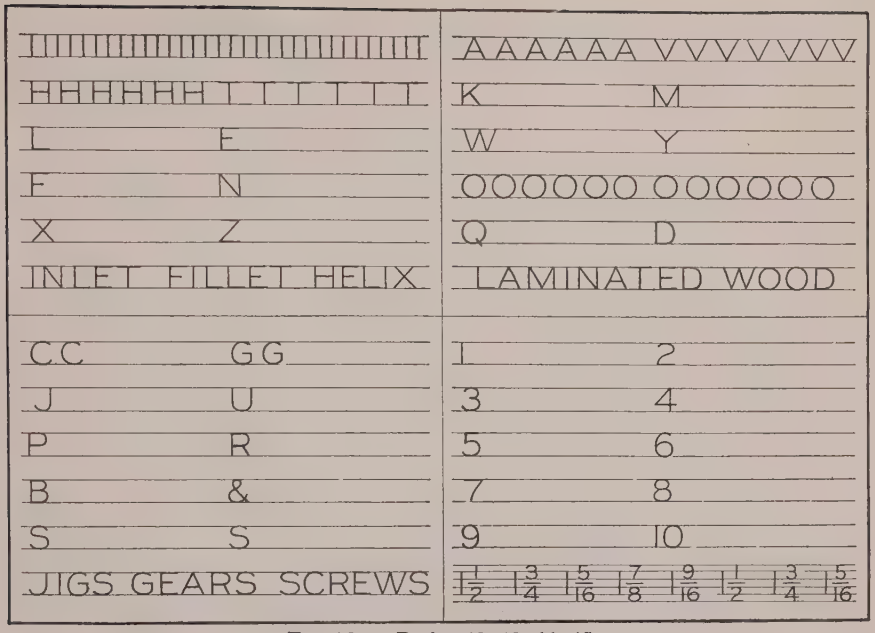

I
H H H H H H H I I I I I I
L F
F N
X Z
INLET FILLET HELIX
A A A A A A V V V V V V V
K M
W Y
O O O O O O O O O O O O O
Q D
LAMINATED WOOD
C C G G
J U
P R
B &
S S
JIGS GEARS SCREWS
1 2
3 4
5 6
7 8
9 10
1 1/2 1 3/4 1 5/16 1 7/8 1 9/16 1 1/2 1 3/4 1 5/16

FIG. 384.—Probs. 42, 43, 44, 45.

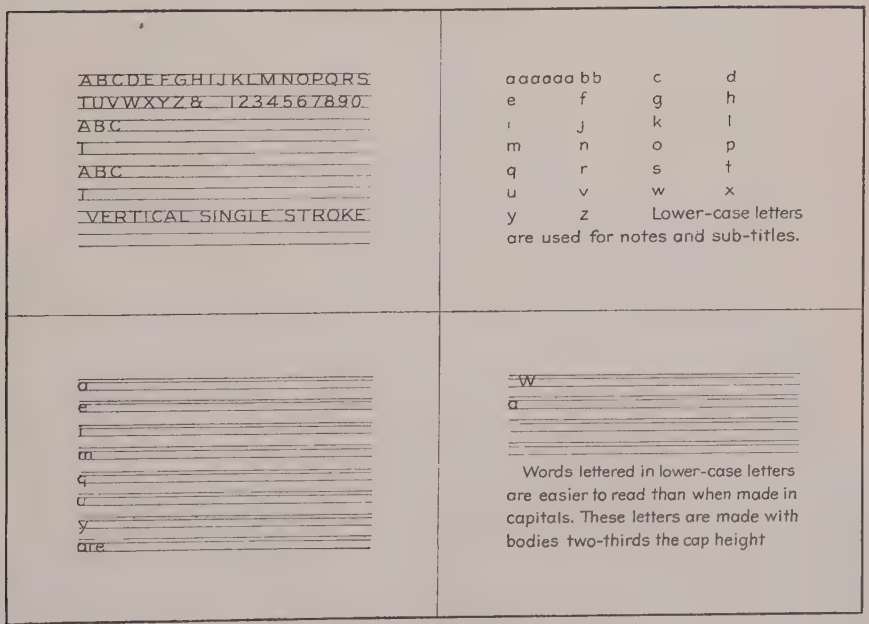
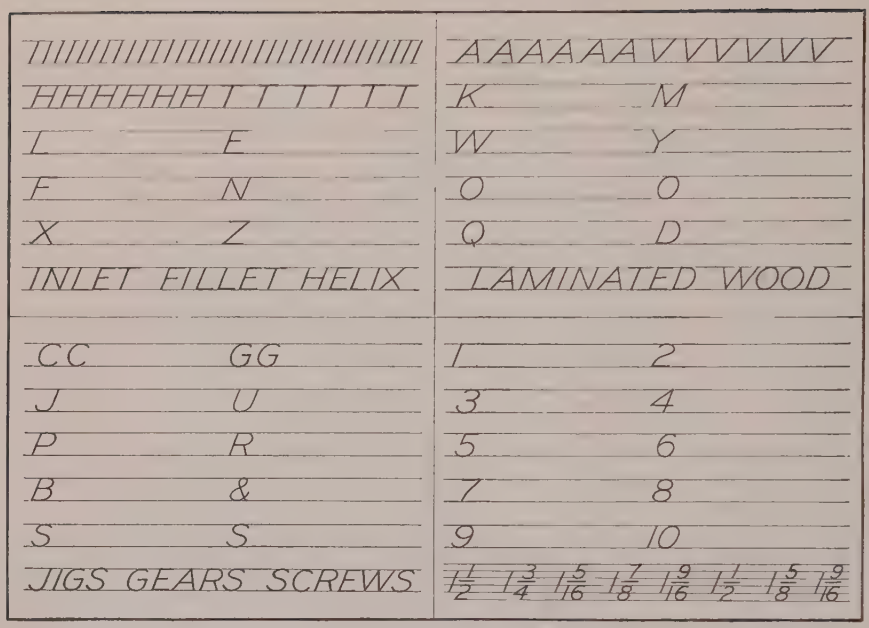

A B C D E F G H I J K L M N O P Q R S
T U V W X Y Z & 1 2 3 4 5 6 7 8 9 0
A B C
I
A B C
I
VERTICAL SINGLE STROKE
a a a a a a b b c d
e f g h
i j k l
m n o p
q r s t
u v w x
y z Lower-case letters
are used for notes and sub-titles.
a
e
i
m
q
u
y
are
w
a
Words lettered in lower-case letters
are easier to read than when made in
capitals. These letters are made with
bodies two-thirds the cap height

FIG. 385.—Probs. 46, 47, 48, 49.


T T T

Prob. 54. Fig. 387 (upper left-hand space). Rule guide lines $\frac{3}{16}''$ apart, starting $1\frac{1}{4}''$ over and $1\frac{3}{16}''$ down. Make first two lines in pencil. Make next two lines very lightly in pencil and go over them with pen and ink. Use Gillott 404 pen. Make fifth and sixth lines in ink without first penciling. Seventh line in pencil. Eighth line in ink.

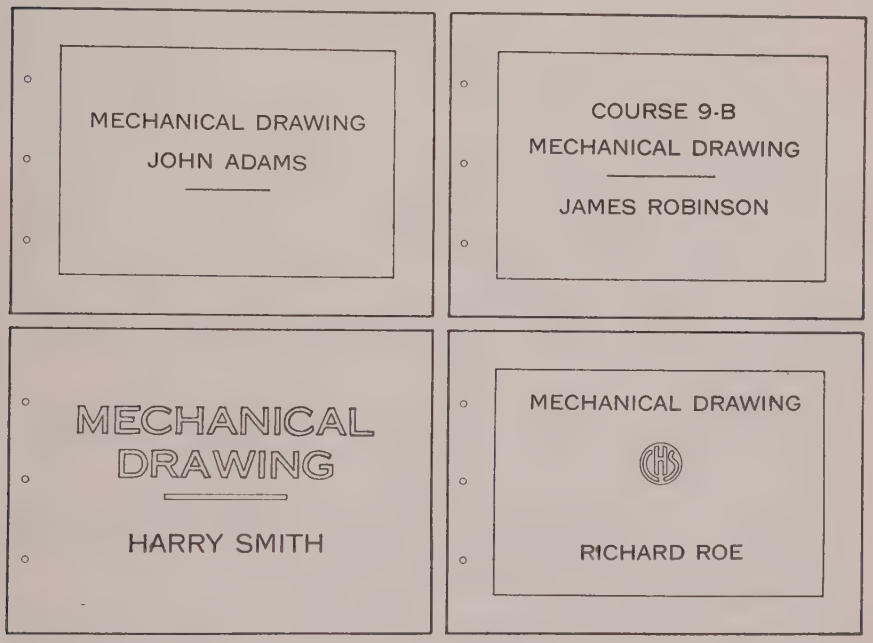


FIG. 388.—Prob. 58. Title page.

Prob. 55. Fig. 387 (upper right-hand space). Single-stroke inclined lower case in pencil. Rule guide lines as shown in lower left-hand space. Start $1\frac{1}{4}''$ over and $1\frac{3}{16}''$ down. The bodies of the letters are $\frac{1}{8}''$ high. The first space is $\frac{1}{16}''$ down, the next $\frac{1}{8}''$ and the next $\frac{3}{16}''$. Repeat until there are guide lines for eight lines of letters. Complete each line. Study Fig. 38.

Prob. 56. Fig. 387 (lower left-hand space). Same as Prob. 55, except that the lettering is to be done directly in ink.

Prob. 57. Fig. 387 (lower right-hand space). Rule as for Prob. 55. Letter the sentence first in pencil, then below, directly in ink.

Title Page.

Prob. 58. Design a title page. Suggestions for composition are shown in Fig. 388.

Group IV. Shape Description.

228. The problems in this group are for practice in representing objects by views in order to gain a thorough understanding of the theory of shape description. Chapter IV should be studied carefully before beginning the problems in this group. Views and pictures are given for some of the problems to assist the student in visualizing the object. In other problems two views are given, from which the student is to work out the third view. In still other problems pictures are given from which the student is required to determine what views are necessary, the plan and arrangement of the views in the working space, and then to work out the views.

Probs. 59, 60, 61, 62. Fig. 389. Lay out an $11'' \times 17''$ sheet, as in Fig. 336, and divide the working space into four equal parts. In each of the spaces draw three views of the block as shown. A picture of each block is given and two of the three views with dimensions. Complete the three views using full-size scale, and letter the record strip. When the sheet is finished, it will appear as shown in Fig. 390. The record strip will contain the title (**"Shape Description Blocks"**), the scale ("Full Size"), and the date. See Figs. 336 and 337.

Probs. 63, 64, 65, 66. Fig. 391. Draw three complete views of each of the **adjusting blocks.** Do not copy the pictures.

Probs. 67, 68, 69, 70. Fig. 392. Draw three complete views of each of the **slide blocks.** No pictures are given for these problems but the student should study the views until the shapes represented are understood.

Probs. 71, 72, 73, 74. Fig. 393. Draw three complete views of each of the **support blocks.** Note that each of these blocks has an inclined surface. Compare with Fig. 55.

Probs. 75, 76, 77, 78. Fig. 394. Draw three complete views of each of the **adjusting blocks.** Note the position of the inclined surface on each of the blocks.

Probs. 79, 80, 81, 82. Fig. 395. Draw three complete views of each of the **angle blocks.** Study the views until the shapes represented are understood.

Probs. 83, 84, 85, 86. Fig. 396. Draw three complete views of each of the **angle blocks.** Study the views until the shapes represented are understood.

Probs. 87, 88, 89, 90. Fig. 397. Draw three complete views of each of the **links.** Refer to Figs. 61 to 64.

Probs. 91, 92, 93, 94. Fig. 398. Draw three complete views of each of the **holders.** Refer to Figs. 61 to 64.

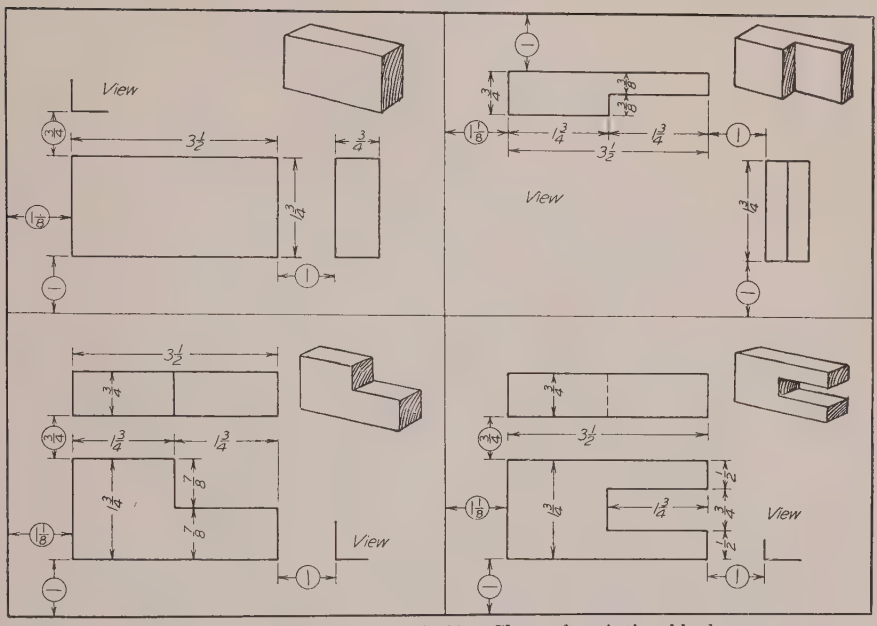


FIG. 389.—Probs. 59, 60, 61, 62. Shape description blocks.

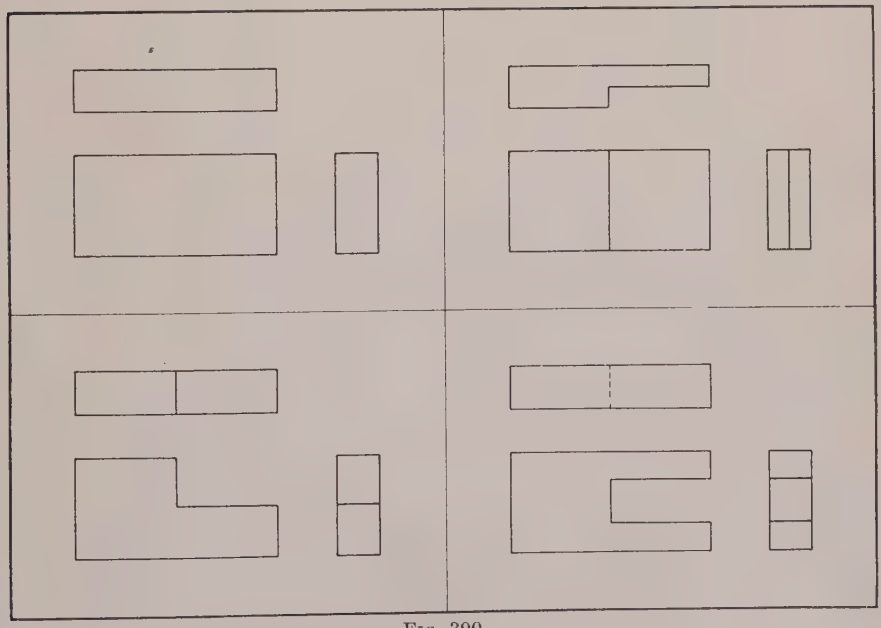


FIG. 390.

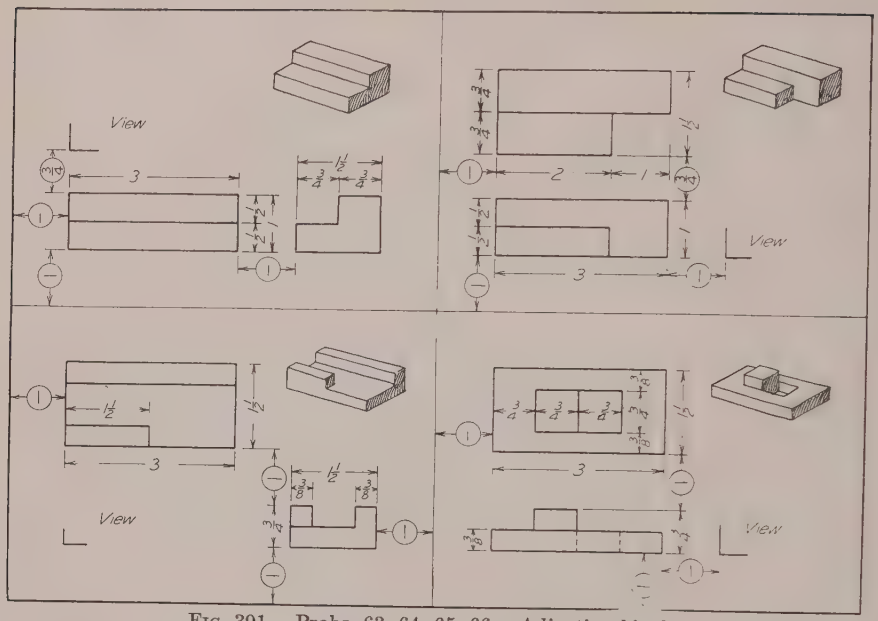


FIG. 391.—Probs. 63, 64, 65, 66. Adjusting blocks.

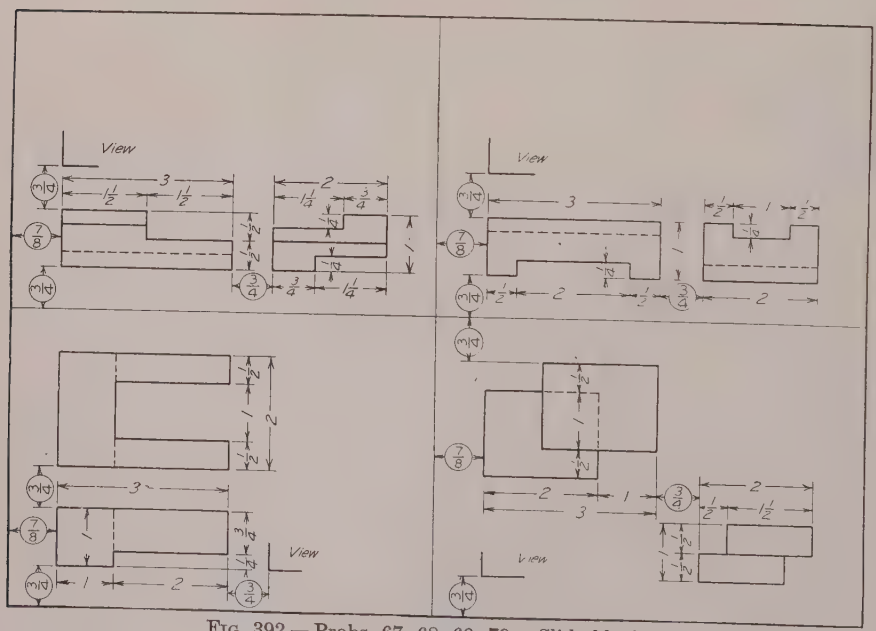


FIG. 392.—Probs. 67, 68, 69, 70. Slide blocks.

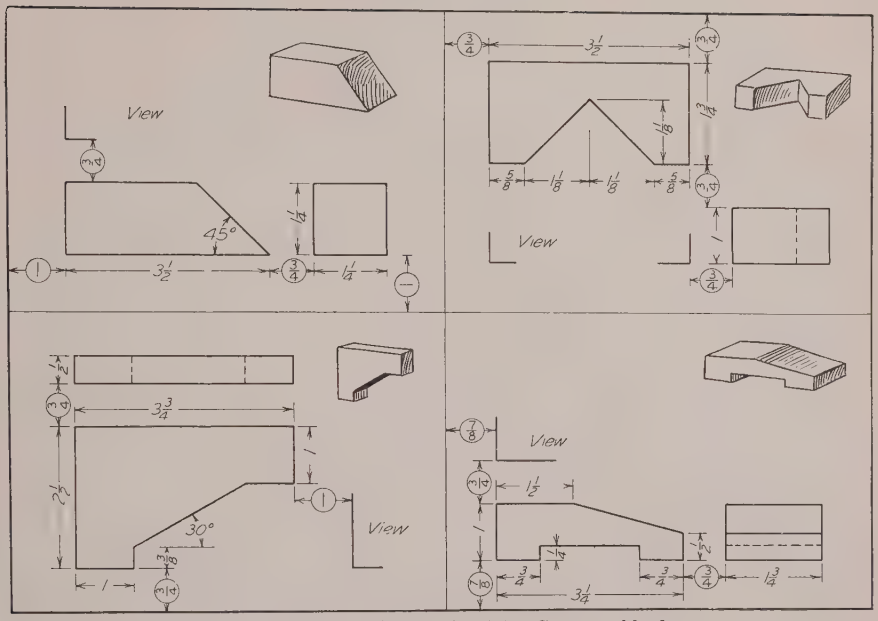


FIG. 393.—Probs. 71, 72, 73, 74. Support blocks.

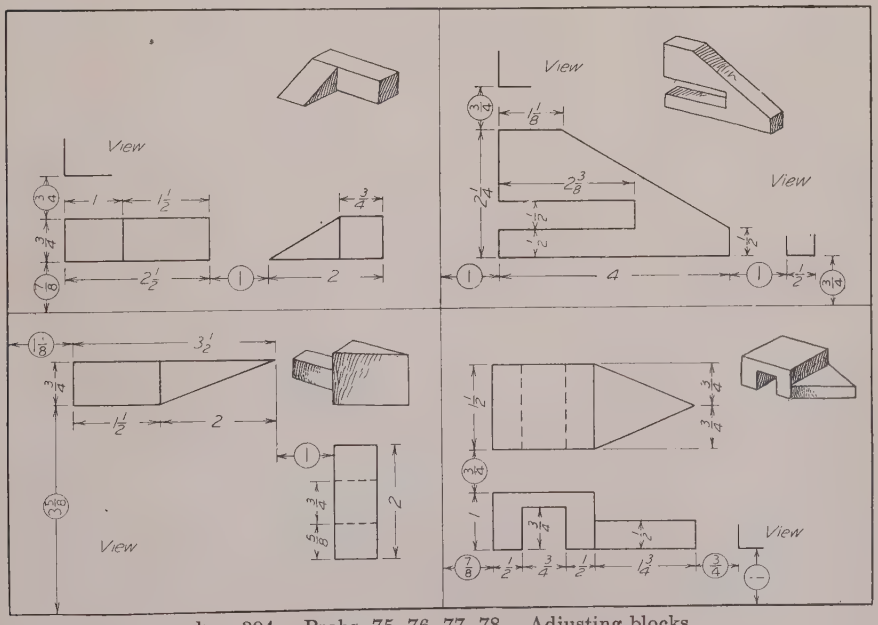


FIG. 394.—Probs. 75, 76, 77, 78. Adjusting blocks.

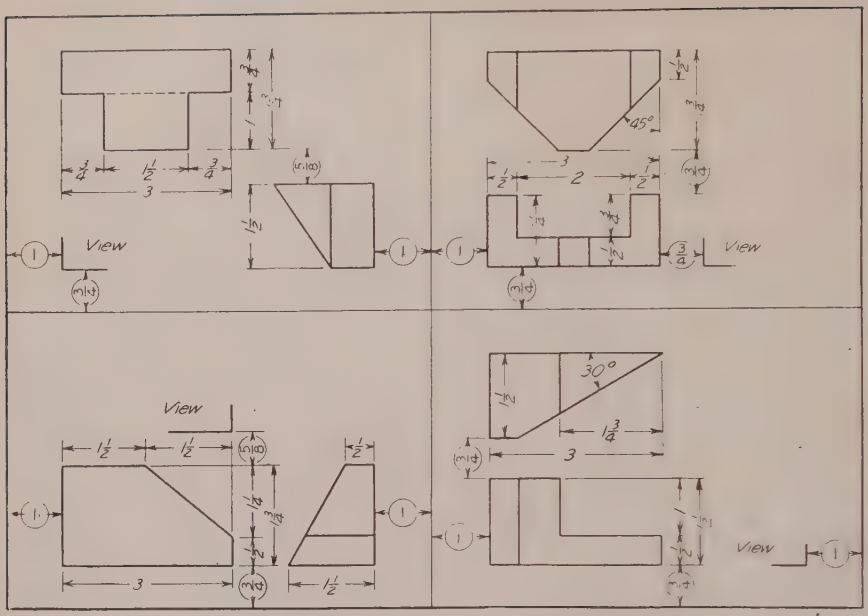


FIG. 395.—Probs. 79, 80, 81, 82. Angle blocks.

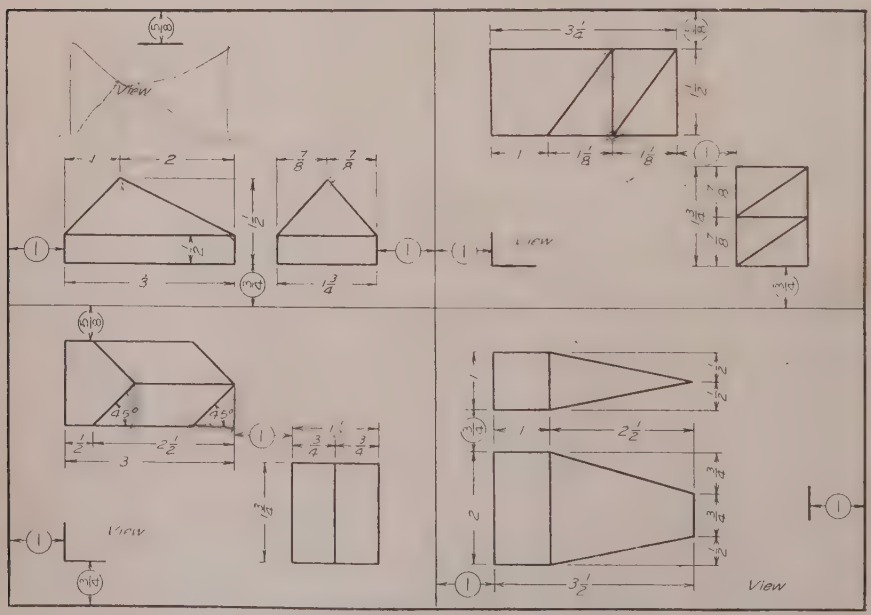


FIG. 396.—Probs. 83, 84, 85, 86. Angle blocks.

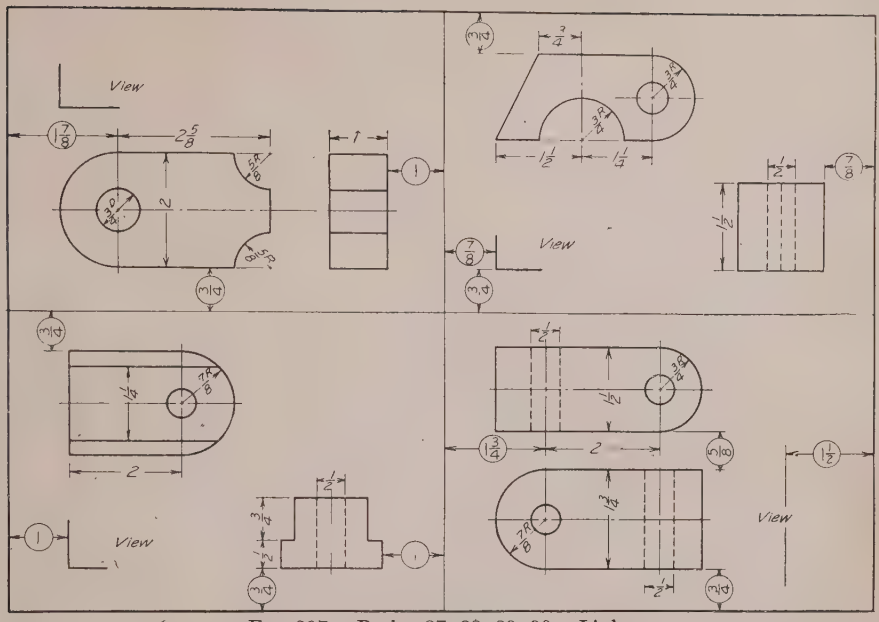


FIG. 397.—Probs. 87, 88, 89, 90. Links.

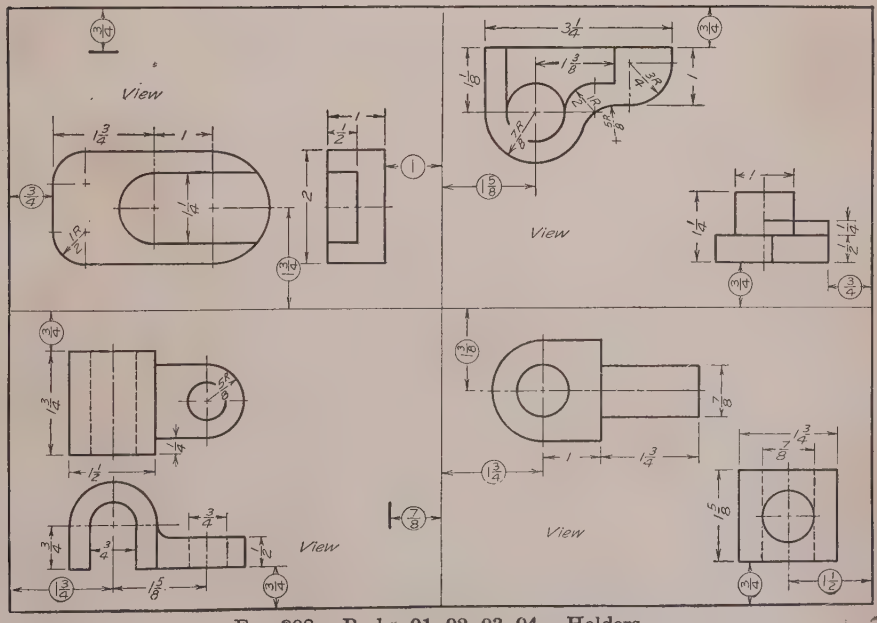


FIG. 398.—Probs. 91, 92, 93, 94. Holders.

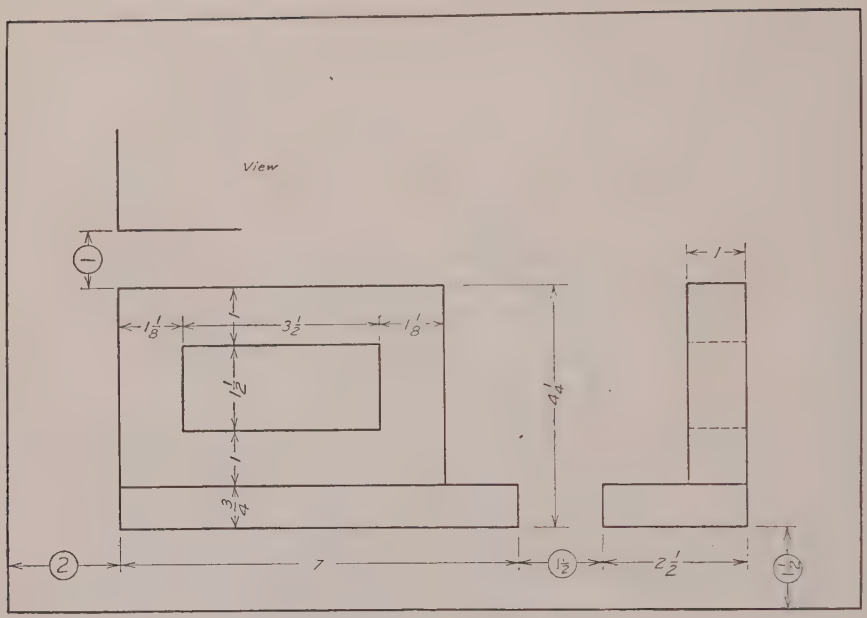


Fig. 399.—Prob. 95. Support.

Prob. 95. Fig. 399. The front and side views of a **support** are shown and located. Draw three complete views. Try to visualize the object as if it were standing before you. Making a freehand pictorial sketch of it on a piece of scratch paper will aid in visualization.

Prob. 96. Fig. 400. On one of the views of each of the objects, *A* to *S*, a line is missing. Visualize the object and make a freehand sketch of the views, supplying the missing line.

Prob. 97. Fig. 401. The top and side views of a **slotted bracket** are shown. Draw three complete views.

Prob. 98. Fig. 402. Given two views of a **fulcrum.** Draw three complete views. First draw front and side views of the base, then draw the 60° lines, using the 30°–60° triangle. The height of the fulcrum is found in the side view where the 60° lines cross and is then projected across to the front view. Draw the top view to complete the drawing.

Prob. 99. Fig. 403. Given two views of a **locating support.** Draw the front view first, project to the top view and from these obtain the side view.

Prob. 100. Fig. 404. Given top and front views of a **cast-iron dovetail.** Draw three complete views. In the top view draw the center line and lay off one-half of $1\frac{3}{4}''$ on each side of it. Draw 60° lines to intersect the $\frac{3}{4}''$ depth line.

Prob. 101. Fig. 405. Draw three views of the **dovetail joint** with the two pieces together. Note the 60° lines in the top view.

Prob. 102. Fig. 406. Draw three complete views of the **secondary guide lug.**

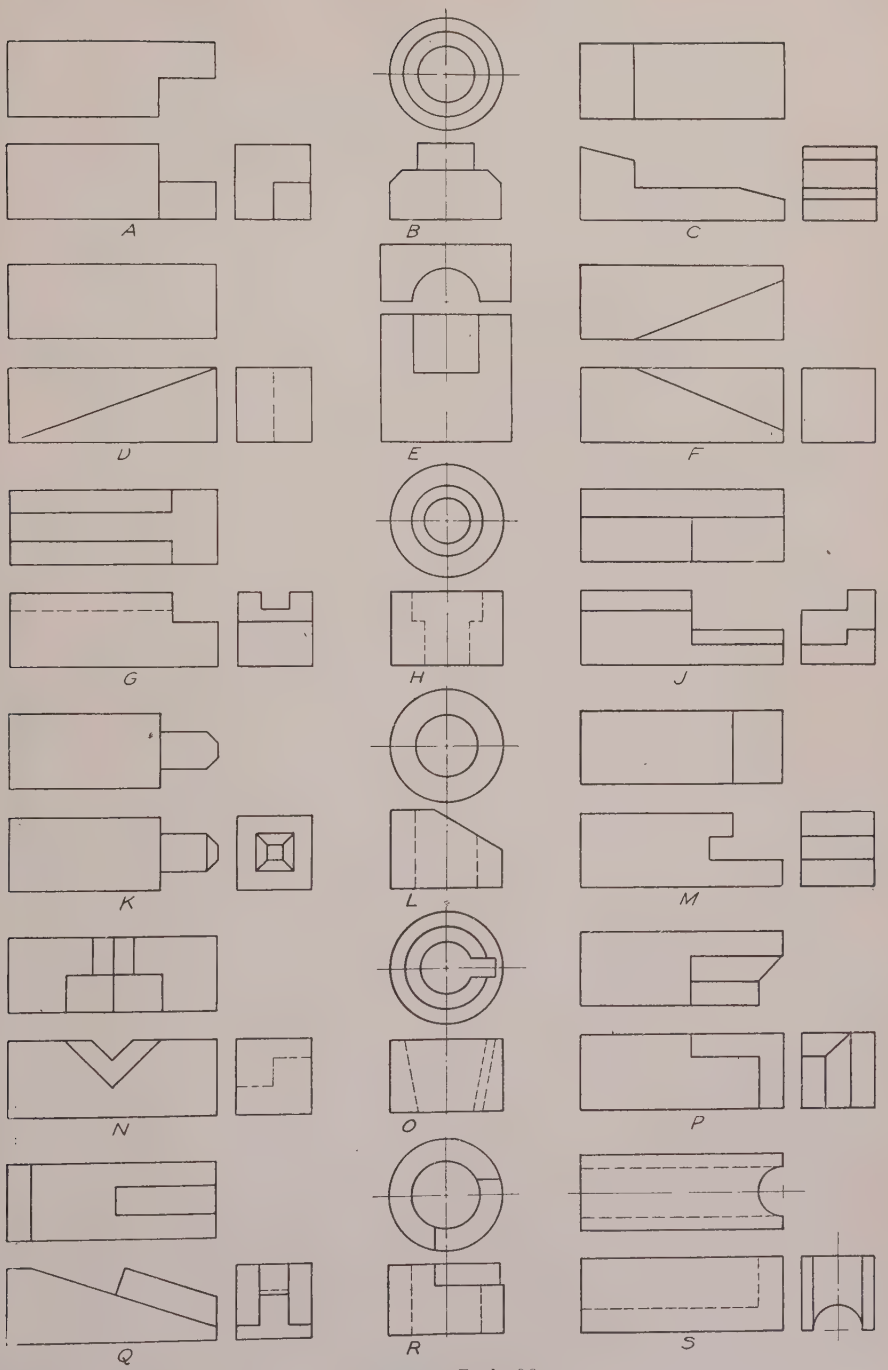


Fig. 400. -Prob. 96.

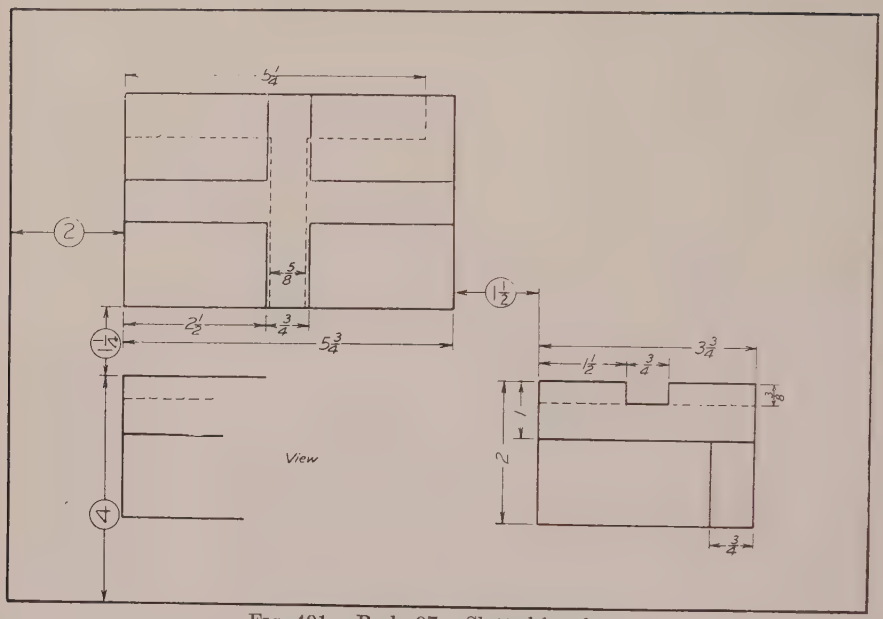


FIG. 401.—Prob. 97. Slotted bracket.

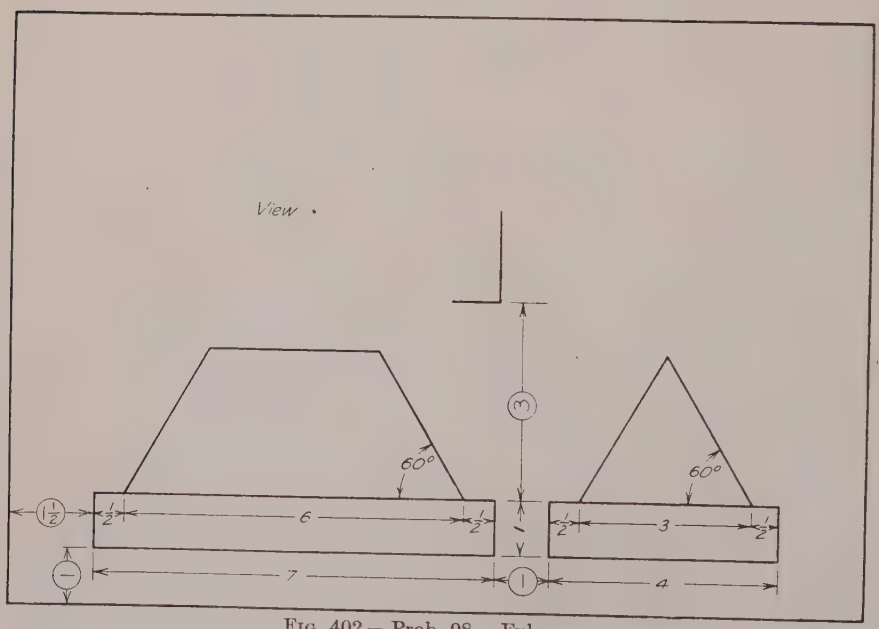


FIG. 402.—Prob. 98. Fulcrum.

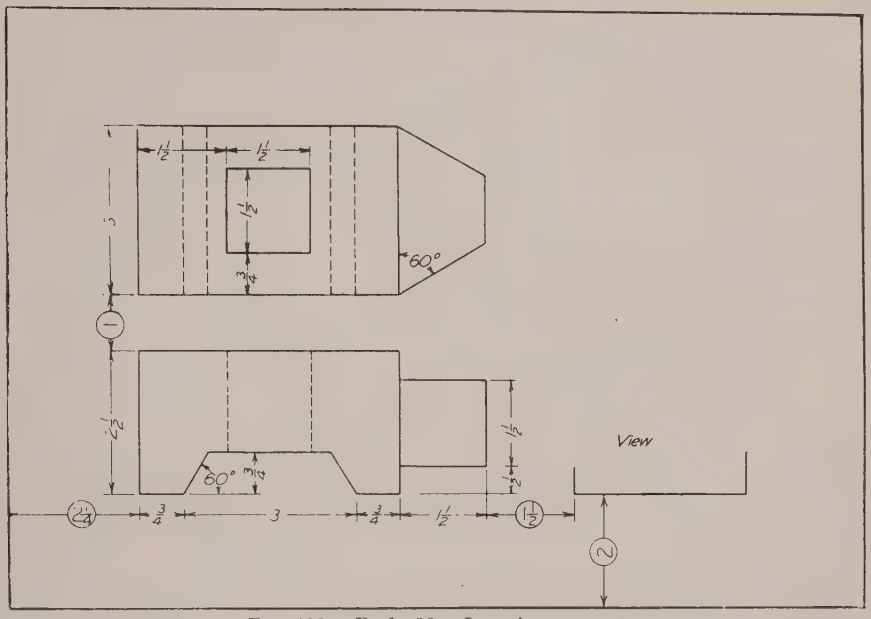


FIG. 403.—Prob. 99. Locating support.

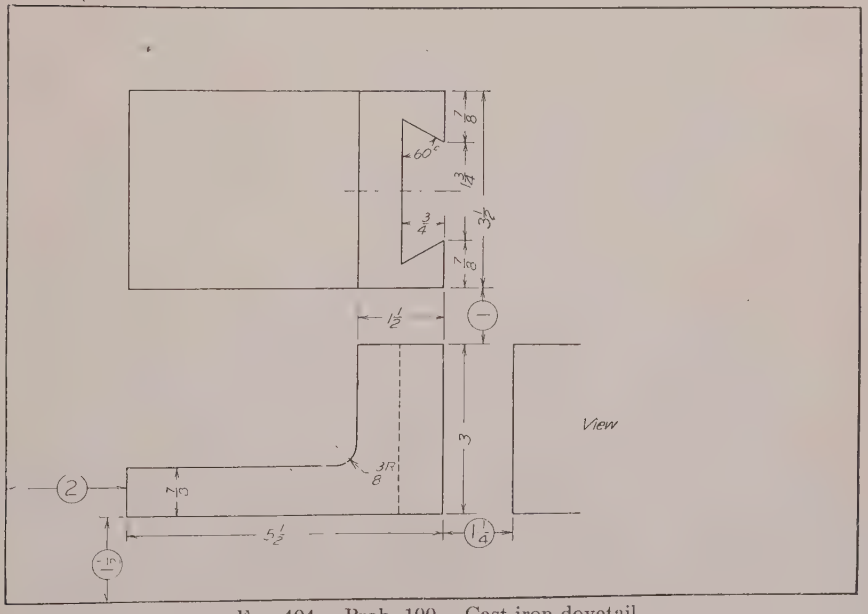


FIG. 404.—Prob. 100. Cast-iron dovetail.

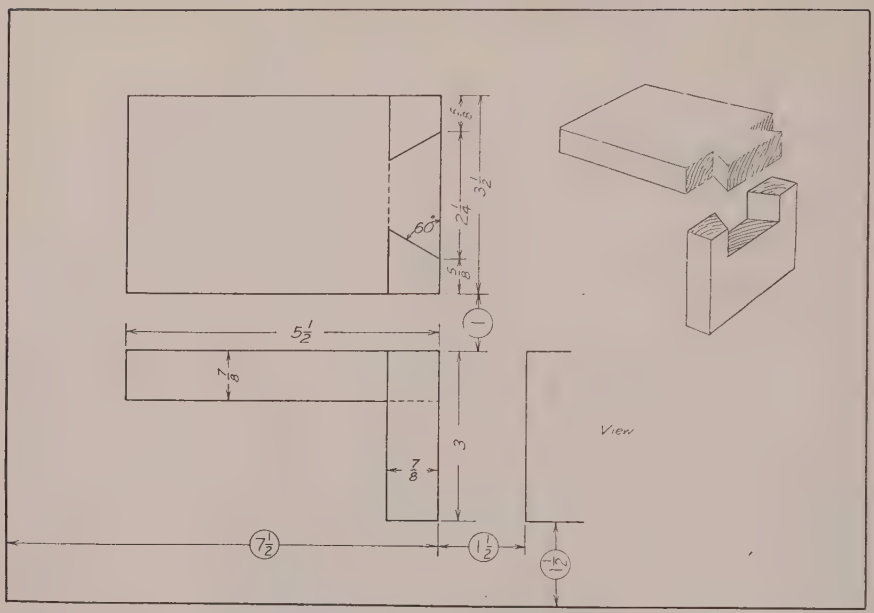


FIG. 405.—Prob. 101. Dovetail joint.

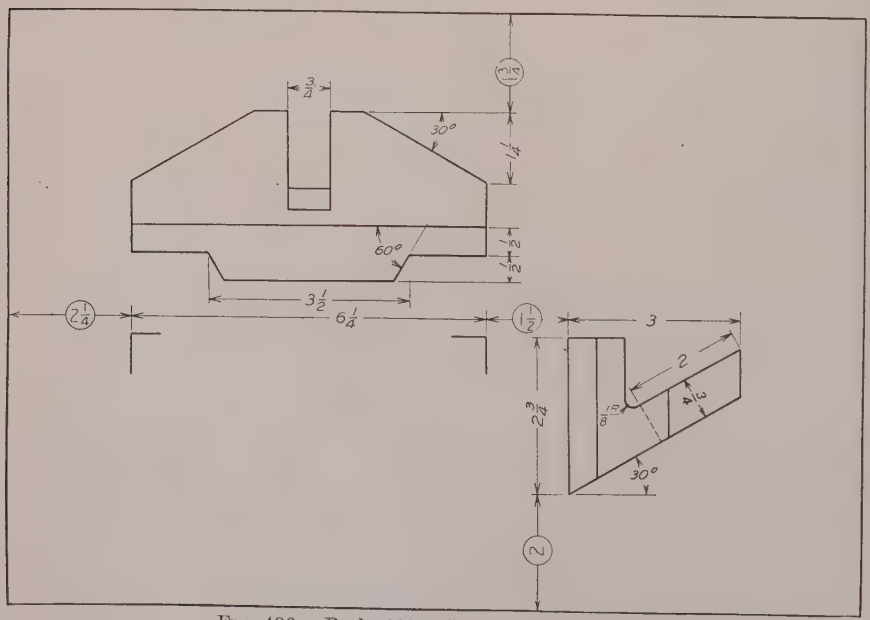


FIG. 406.—Prob. 102. Secondary guide lug.

229. Placing Views.—The location of the views for the preceding problems has been given. When drawings are made from objects or for things which have not been made, it is necessary for the draftsman to be able to place the views so that they will go in the space to advantage. This is done by considering the space necessary for each view and comparing the total room required with the size of the sheet.

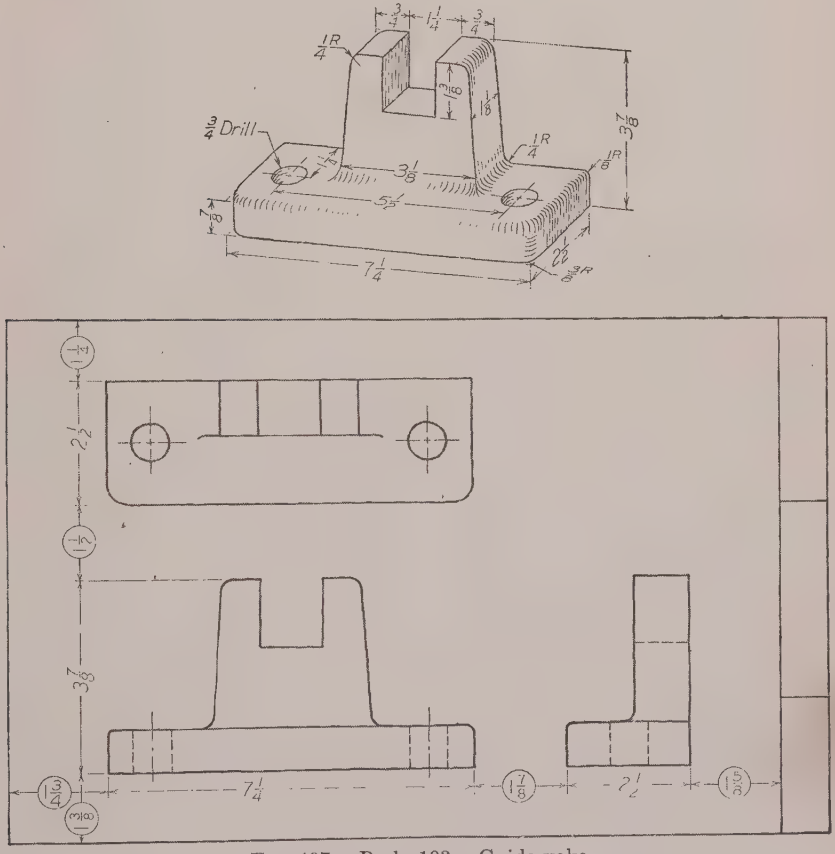


FIG. 407.—Prob. 103. Guide yoke.

Note the object of Fig. 407. Working space on sheet is $10\frac{1}{2}'' \times 15''$. The top view will require $2\frac{1}{2}''$ in a vertical direction and the front view $3\frac{7}{8}''$. Allowing (say) $1\frac{1}{2}''$ between views, the total is $7\frac{7}{8}''$. Subtracting $7\frac{7}{8}''$ from $10\frac{1}{2}''$ (the height of the space), we have left $2\frac{5}{8}''$ to be divided between top and bottom. In the layout sketch (Fig. 407) the base line of the front view has been placed $1\frac{3}{8}''$ up, which leaves $1\frac{1}{4}''$ above the top line of the top view. The sum of the horizontal dimensions of the front and side views is $9\frac{3}{4}''$. Allowing $1\frac{7}{8}''$ between views, there is left $3\frac{3}{8}''$ for the two side spaces. In Fig. 407 the left space is $1\frac{3}{4}''$ and the right is $1\frac{5}{8}''$. It is not necessary to have the spaces exactly alike either between the views or around them.

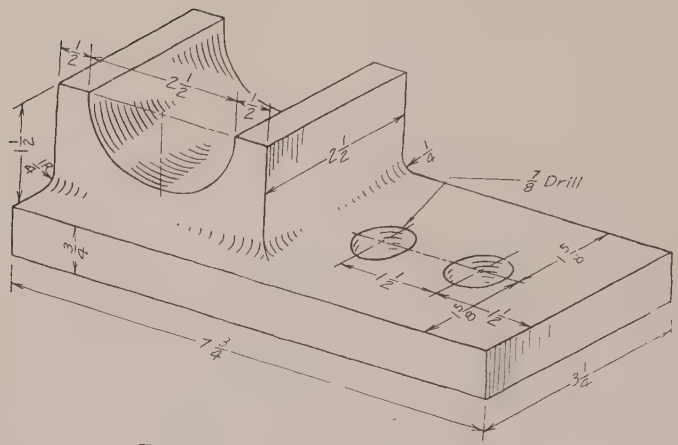


FIG. 408.—Prob. 104. Horizontal guide.

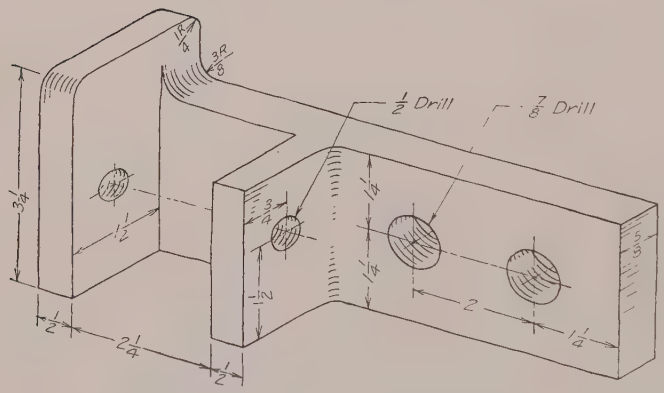


FIG. 409.—Prob. 105. Vertical guide.

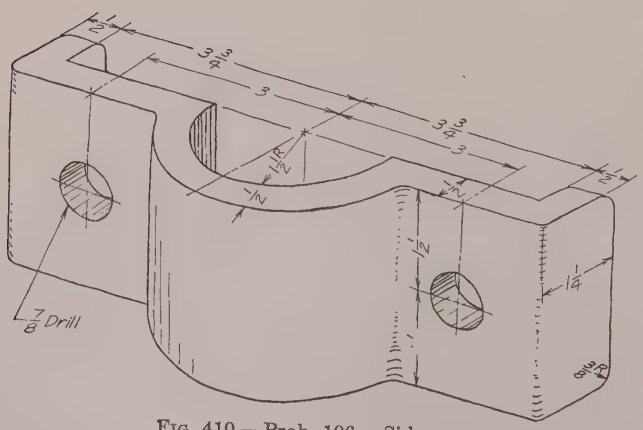


FIG. 410.—Prob. 106. Side cap.

Prob. 103. Fig. 407. Draw three complete views of the **guide yoke.** Make a sketch similar to the one illustrated in Fig. 407 and check the computations for the spacing of the views before beginning the problem.

Prob. 104. Fig. 408. Draw three complete views of the **horizontal guide.** First consider the choice of views. Then make a freehand sketch and work out the placing of the views as explained in Art. 229.

Prob. 105. Fig. 409. Draw three complete views of the **vertical guide.** First consider the choice of views. Then make a freehand sketch and work out the placing of the views as explained in Art. 229.

Prob. 106. Fig. 410. Draw three complete views of the **side cap.** First consider the choice of views. Then make a freehand sketch and work out the placing of the views as explained in Art. 229.

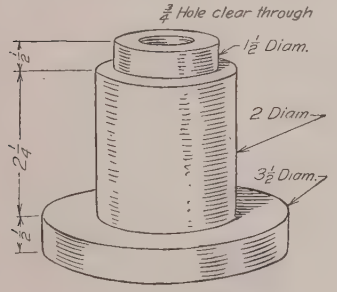


FIG. 411.—Prob. 107. Cast iron collar.

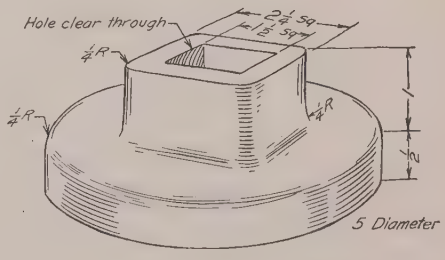


FIG. 412.—Prob. 108. Socket.

Prob. 107. Fig. 411. Draw two complete views of the **cast iron collar.**

Prob. 108. Fig. 412. Draw two complete views of the **socket.**

Suggested Spacing.—For a sheet containing Probs. 107 and 108, or 109 and 110, the views required for each of these pieces would obviously be a top view and a front view. Draw a vertical center line for the left-hand figure about 4″ from the left border. Draw a base line about 1½″ from the bottom and a horizontal center line for the top view 6″ above the base line. For the right-hand figure draw a vertical center line about 4″ from the right border, base line 1½″ from bottom border and center line for top view 5¼″ above base line of front view.

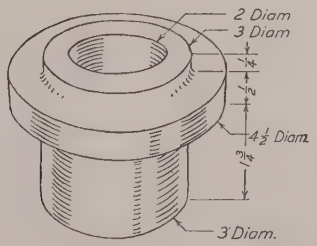


FIG. 413.—Prob. 109. Stud bushing.

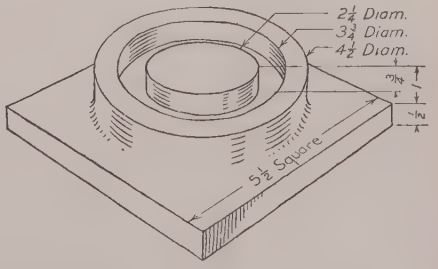


FIG. 414.—Prob. 110. Swivel base.

Prob. 109. Fig. 413. Draw two complete views of the **stud bushing.**

Prob. 110. Fig. 414. Draw two complete views of the **swivel base.**

Prob. 111. Fig. 415. Draw two complete views of the **centering plate.** Four holes are to be drilled and countersunk in plate for ½″ cap screws (see Table V for dimensions).

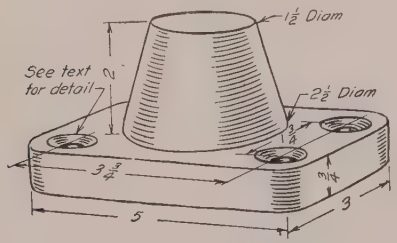


Fig. 415.—Prob. 111. Centering plate.

Prob. 112. Fig. 416. Draw front and side views of the **bearing.**

Suggested Spacing.—For a sheet containing Probs. 111 and 112, or 113 and 114, draw a vertical center line for the left-hand figure about 4″ from the left border. Then work out the spacing in a vertical direction on the center line as explained in Art. 229 on Placing Views. In a similar manner work out the placing of the views for the right-hand figure in the remaining space.

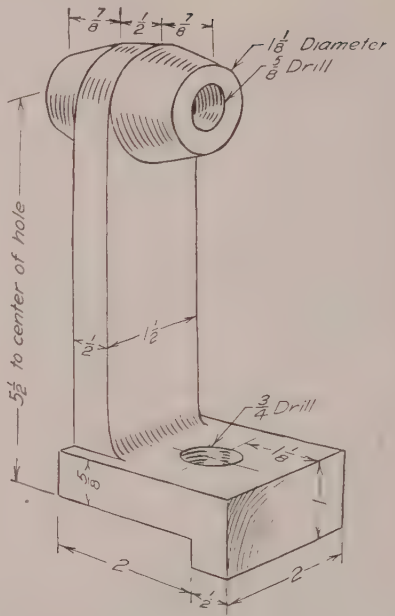


Fig. 416.—Prob. 112. Bearing.

Prob. 113. Fig. 417. Draw two complete views of the **rocker block.** The ½″ holes extend through the piece.

Prob. 114. Fig. 418. Draw three complete views of the **vertical bracket.**

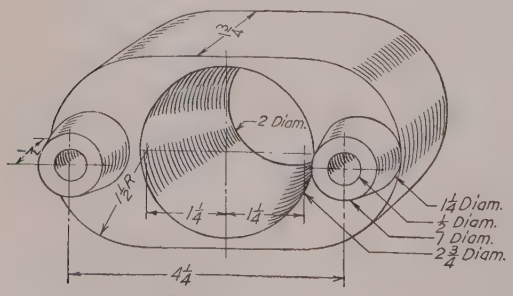


Fig. 417.—Prob. 113. Rocker block.

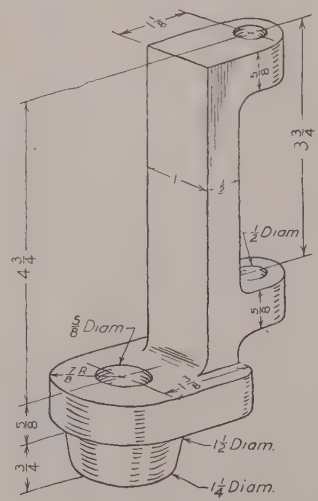


Fig. 418.—Prob. 114. Vertical bracket.

Group V. Sections.

230. Study carefully Chap. VI. The cut surface is indicated by section lining with fine uniformly spaced lines at 45°; for these problems about $\frac{1}{16}''$ apart.

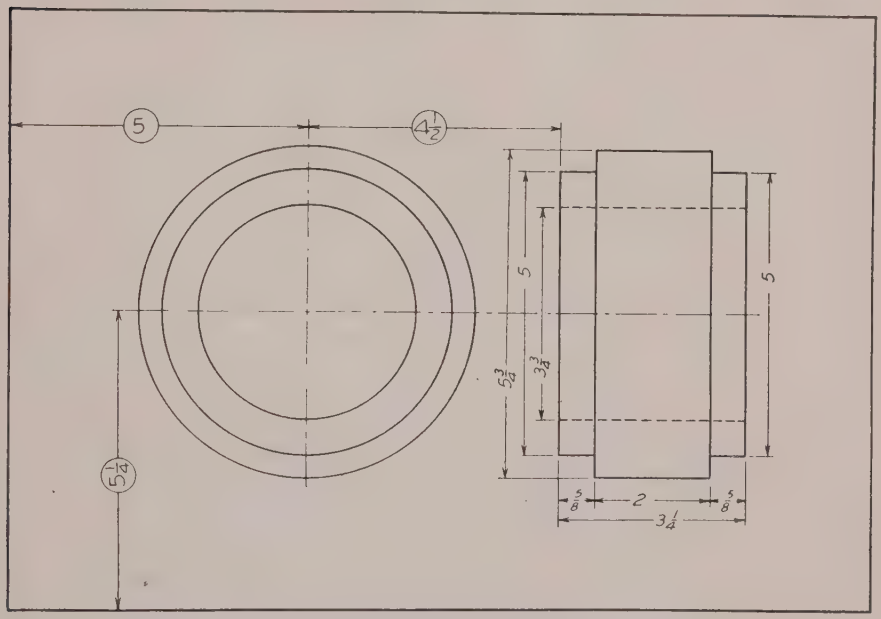


FIG. 419.—Prob. 115. Cylindrical spacer.

Prob. 115. Fig. 419. Make a two-view drawing of the **cylindrical spacer,** the right-hand view to be a full section.

Prob. 116. Fig. 420. Make a two-view drawing of the **clamping disk,** the right-hand view to be a full section.

Prob. 117. Fig. 421. Make a two-view drawing of the **reducing spacer,** the right-hand view to be a full section.

Prob. 118. Fig. 422. Make a two-view drawing of the **water piston** body, showing the right-hand view as a half section. Read Art. 45 on half sections.

Prob. 119. Fig. 423. Make a two-view drawing of the **steam piston,** the left-hand view to be a full section.

Prob. 120. Fig. 424. Make a two-view drawing of the **shaft cap,** the left-hand view to be a full section.

Prob. 121. Fig. 425. Make a two-view drawing of the **protected bearing,** showing the right-hand view as a half section. Read Art. 45.

Prob. 122. Fig. 426. Make a two-view drawing of the **hood bearing,** showing the right-hand view in section.

Prob. 123. Fig. 427. Draw three views of the **yoke,** the front view to be in section. Note that there are two pieces, the yoke and the bushing. Read Art. 47 in regard to section lines when two pieces are drawn together (see Fig. 147). The pictorial view is not to be copied.

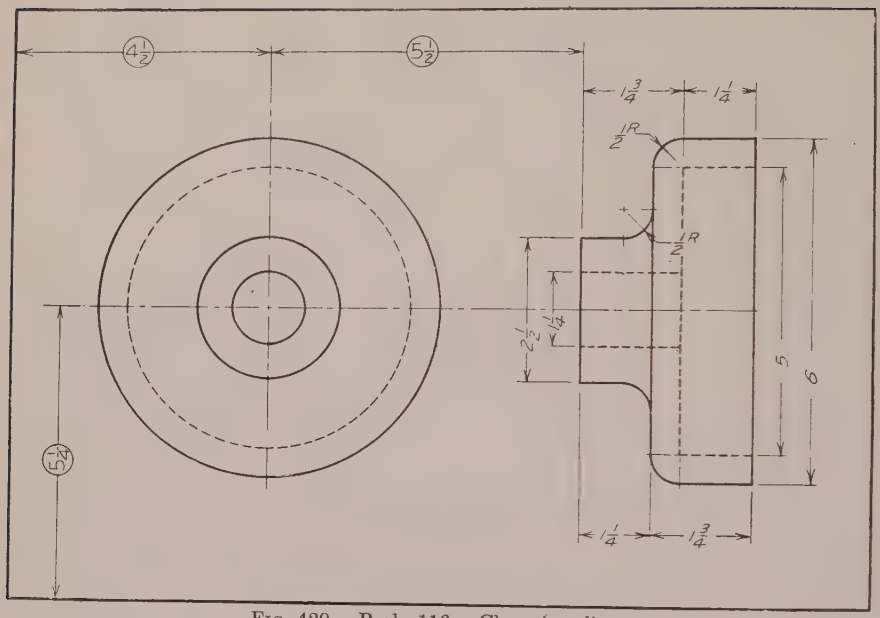


Fig. 420.—Prob. 116. Clamping disc.

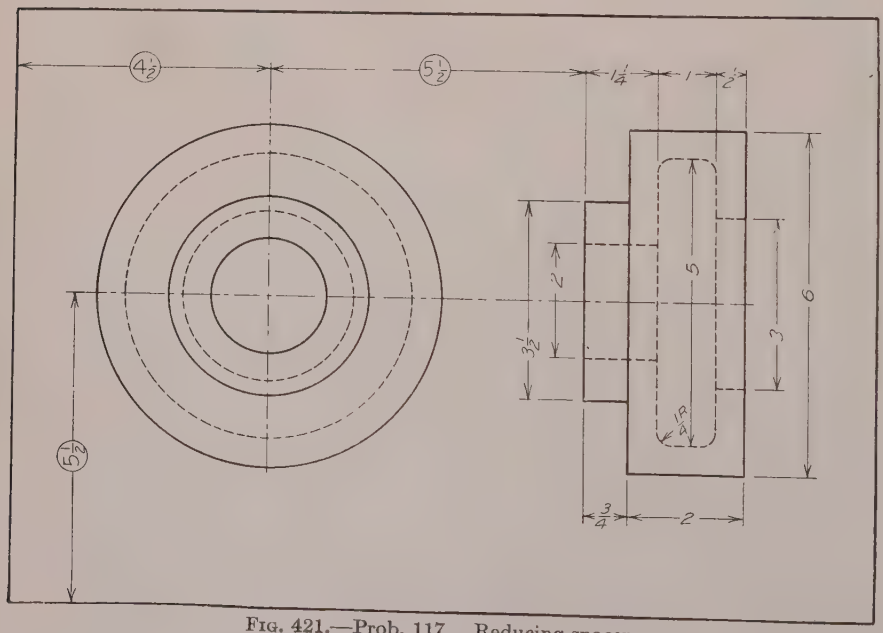


Fig. 421.—Prob. 117. Reducing spacer.

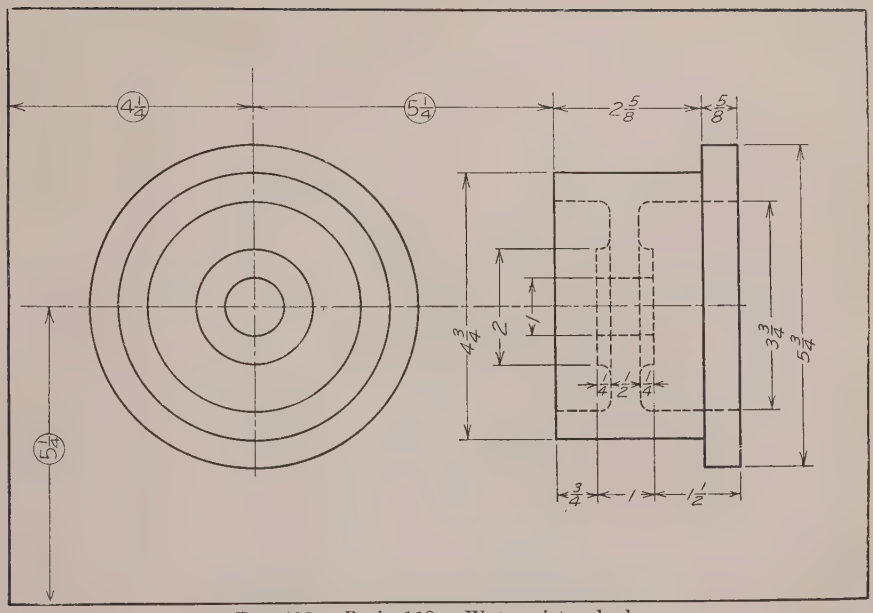


FIG. 422. –Prob. 118. Water piston body.

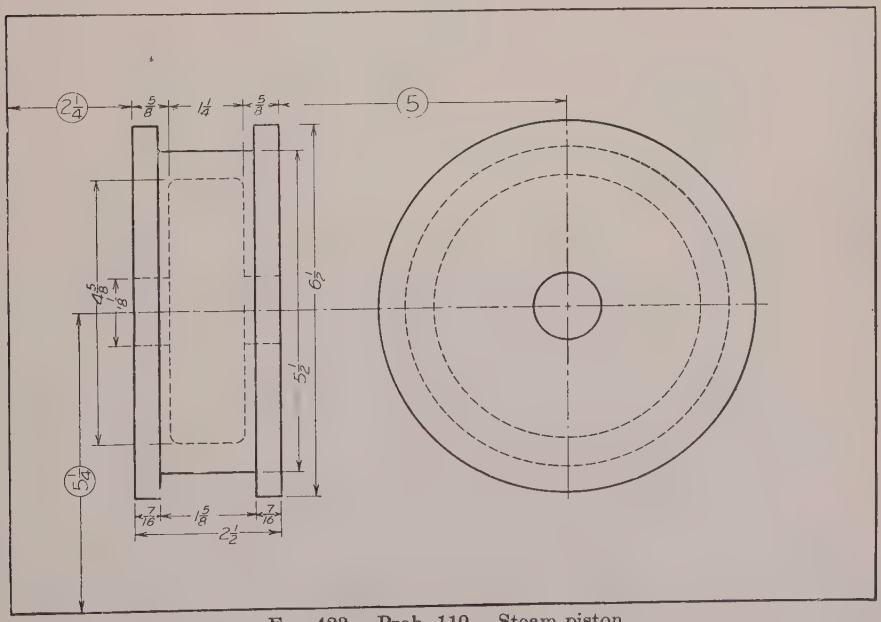


FIG. 423.—Prob. 119. Steam piston.

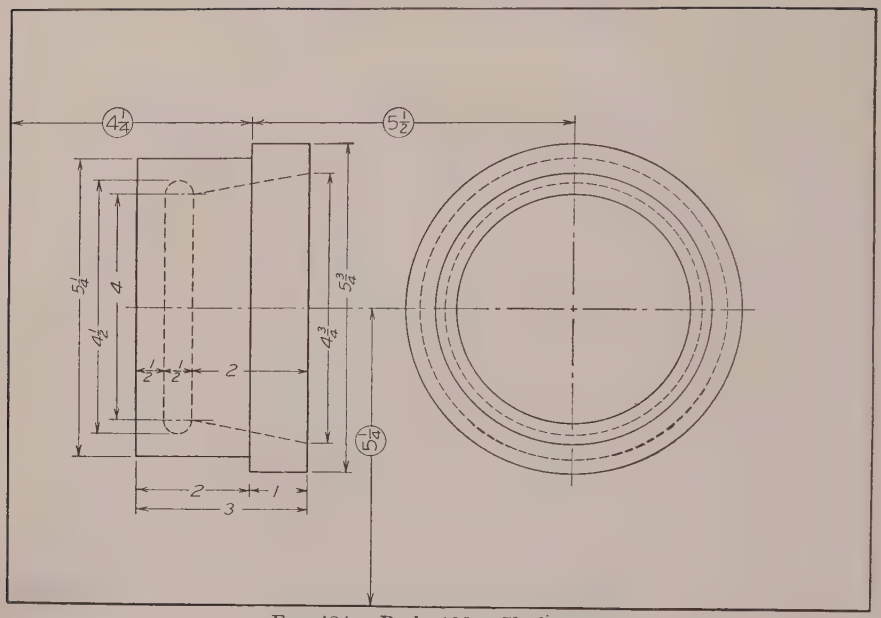


FIG. 424.—Prob. 120. Shaft cap.

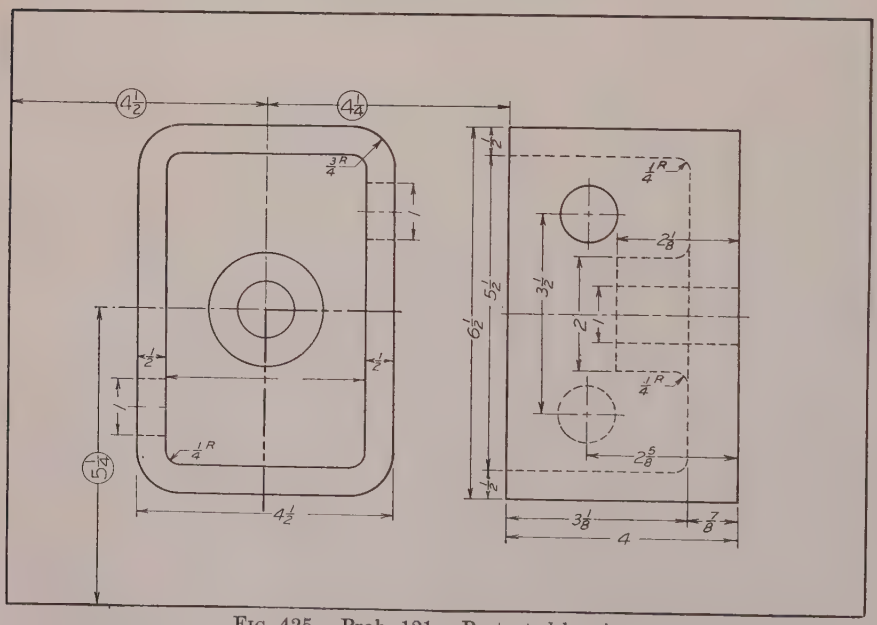


FIG. 425.—Prob. 121. Protected bearing.

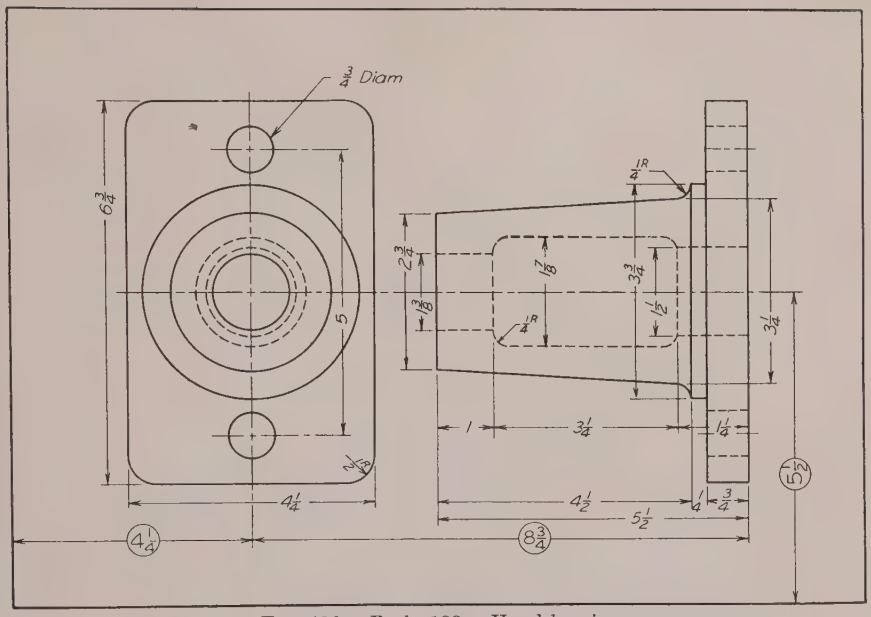


Fig. 426.—Prob. 122. Hood bearing.

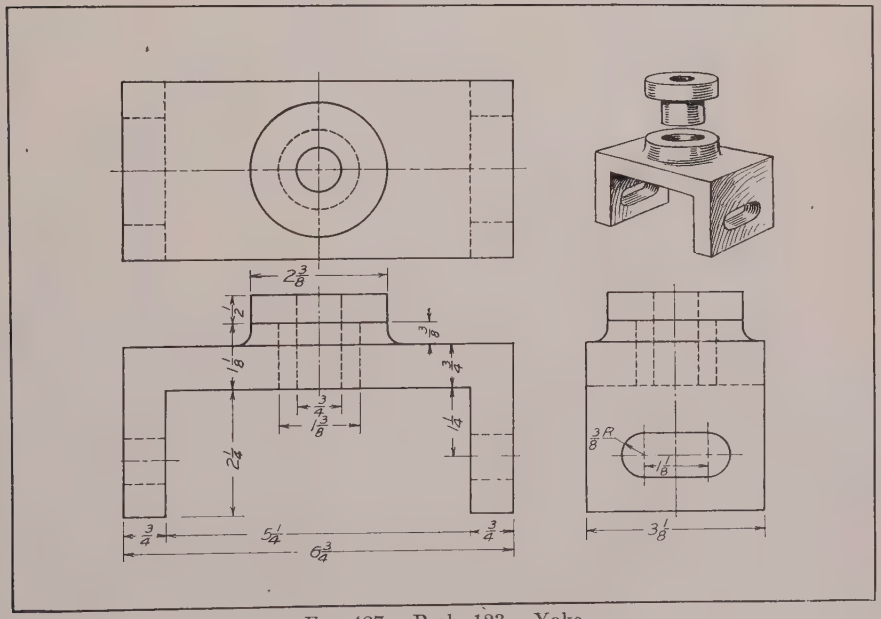


Fig. 427.—Prob. 123. Yoke.

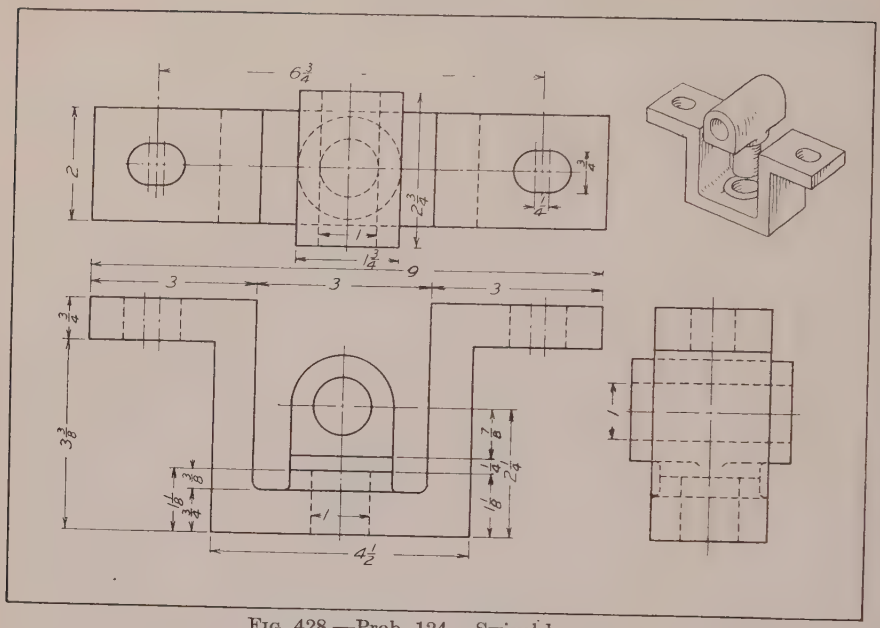


FIG. 428.—Prob. 124. Swivel hanger.

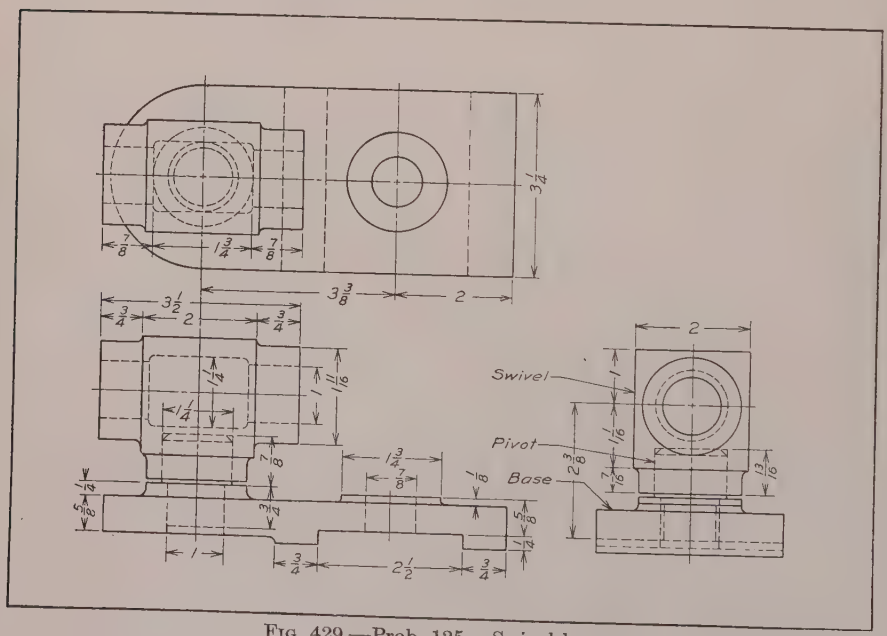


FIG. 429.—Prob. 125. Swivel base.

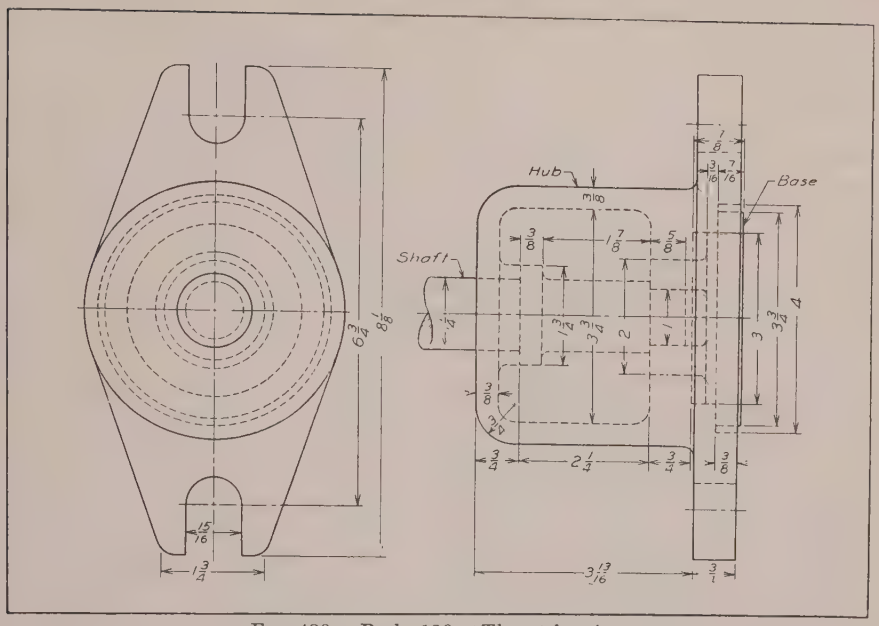


FIG. 430.—Prob. 126. Thrust bearing.

Prob. 124. Fig. 428. Draw three views of the **swivel hanger,** the side view to be a section. Notice that this problem involves the section lining of two adjacent pieces.

The pictorial view is given only as an aid in reading the problem and is not to be included on the student's drawing.

Prob. 125. Fig. 429. Draw three views of the **swivel base,** the front view to be in section.

Prob. 126. Fig. 430. Draw two views of the **thrust bearing,** the right-hand view to be a section. There are three parts, the shaft, hub and base.

The problems in this group have all been section lined as if made of cast iron. Occasionally it is desirable, as an aid in reading a drawing, to use one or more of the symbols for other materials, as stated in Art. 83. In order that the student may become familiar with this symbolic section lining, the following exercise is given.

Prob. 127. Symbolic Section Lining. Fig. 147. Lay off sixteen $1\frac{1}{2}'' \times 2\frac{1}{2}''$ rectangles equally spaced. In these draw the first 12 and a choice of 4 other symbols from Fig. 147. Make the cast-iron section lines about $\frac{1}{8}''$ apart and the others in proportion. Letter the names of the materials represented under each of the rectangles.

Group VI. Auxiliary Views.

231. Study Chap. VII on auxiliary views before beginning the problems. In the layouts of the problems the location is given for the center line or reference line, parallel to the slanting surface, on which the auxiliary view is to be constructed. In the case of symmetrical figures the center line corresponds to the horizontal center line of the top view, as in Prob. 128. For unsymmetrical figures the reference line is usually taken at the back on the top view as in Prob. 129. The projection lines from the front view of the object to the auxiliary view are shown in the layouts to aid in starting the problems. If drawn by the student, they should be extremely light so as not to confuse the result. On practical shop drawings they are never drawn.

Title for sheets containing Probs. 128 and 129 (or alternates from Probs. 130 to 134) is **"Auxiliary Projection."**

Prob. 128. Fig. 431. The figure gives the layout for two problems. Draw the top, front and the complete auxiliary view of the **rectangular prism** as shown.

Prob. 129. Fig. 431. Draw the two views given and the complete auxiliary view of the **triangular prism.**

Probs. 130, 131, 132, 133, 134. Figs. 432, 433, 434, 435, 436. Alternate problems similar to Probs. 128 and 129.

Prob. 135. Fig. 437. Use half of a regular working space. Measure from left-hand and lower margin lines to locate front view. Draw the views as shown and a complete auxiliary view for the **anchor lug.** Note that the hole is not to be drawn in the top view. If worked in the right-hand half of the sheet, measure from the vertical division line instead of the left-hand margin.

Prob. 136. Fig. 438. Use half of regular working space. Measure from left-hand and lower margin lines to locate front view. Draw the views as shown and a complete auxiliary view for the **base anchor.** Note that the cylindrical part is not drawn in the top view. If worked in the right-hand half of the sheet, measure from the vertical division line instead of the left-hand margin.

Prob. 137. Fig. 439. A picture and layout for an **angle stop** are shown in the figure. Draw the two views as given and a part auxiliary view. The picture need not be copied. Dimension if required by instructor. This is the form in which auxiliary projection most frequently occurs in practical work (see Fig. 105).

Prob. 138. Fig. 440. Draw the two views given and an auxiliary view of the slanting face of the **angle support.** The picture is not to be drawn.

Prob. 139. Fig. 441. Using a layout similar to Fig. 444, draw the two views given and from these draw the complete auxiliary view of the **sloping dovetail.**

Prob. 140. Fig. 442. Using a layout similar to Fig. 444, draw the two views given and from these draw the complete auxiliary view of the **shaft holder.**

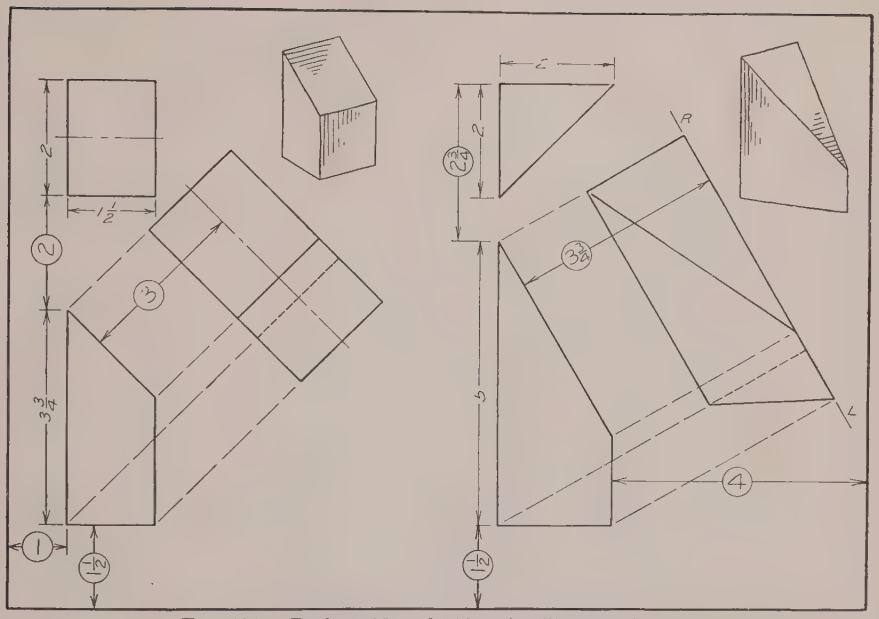


FIG. 431.—Probs. 128 and 129. Auxiliary projection.

In Fig. 431 the rectangular prism is cut at 45° with the vertical. For an alternate problem use 30° and increase the 3¾″ vertical dimension to 5″. The triangular prism is cut to 30° with the vertical. For an alternate problem use 45° and decrease the 5″ dimension to 3½″.

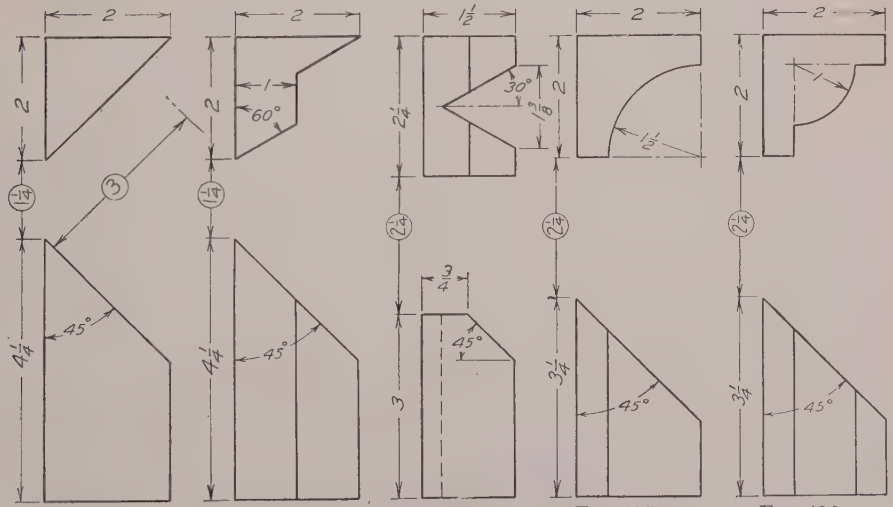


FIG. 432.—Prob. 130.

FIG. 433.—Prob. 131.

FIG. 434.—Prob. 132.

FIG. 435.—Prob. 133.

FIG. 436.—Prob. 134.

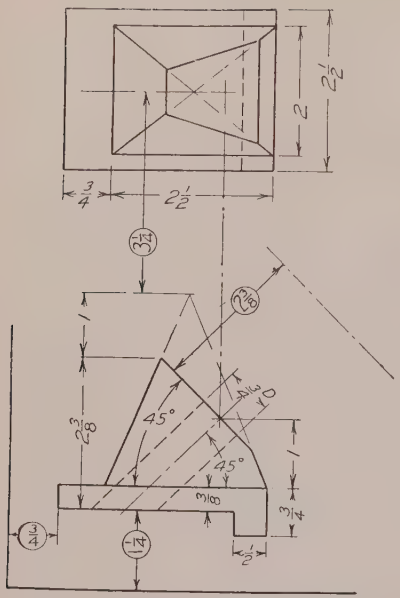


FIG. 437.—Prob. 135. Anchor lug.

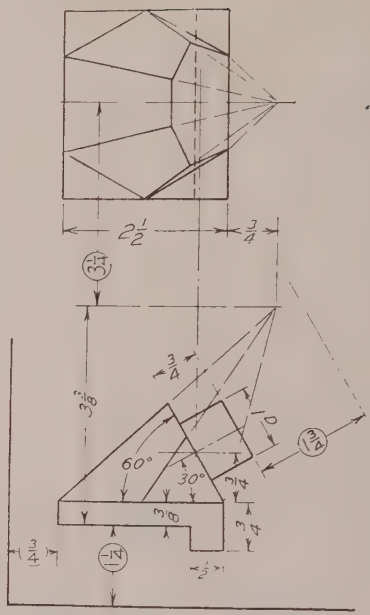


FIG. 438.—Prob. 136. Base anchor.

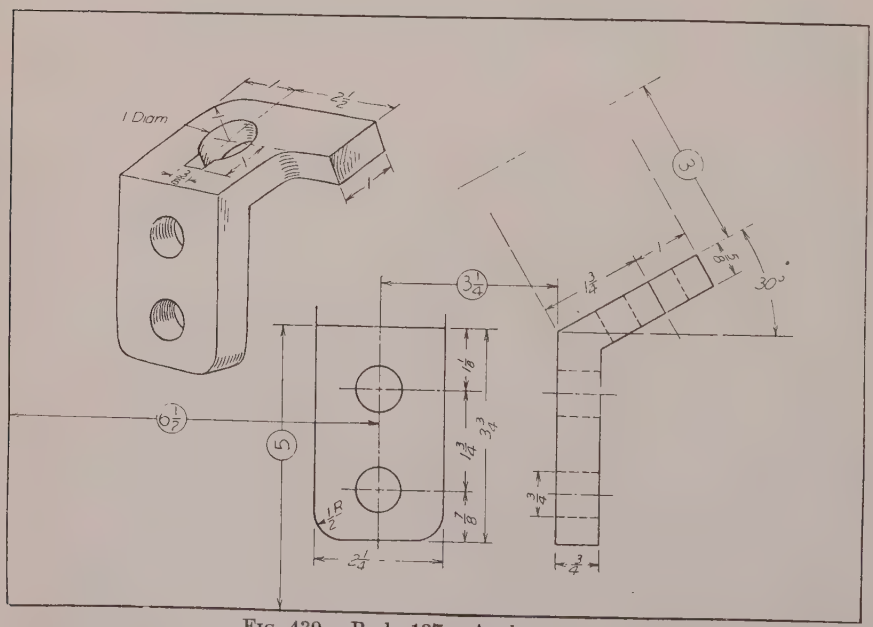


FIG. 439.—Prob. 137. Angle stop.

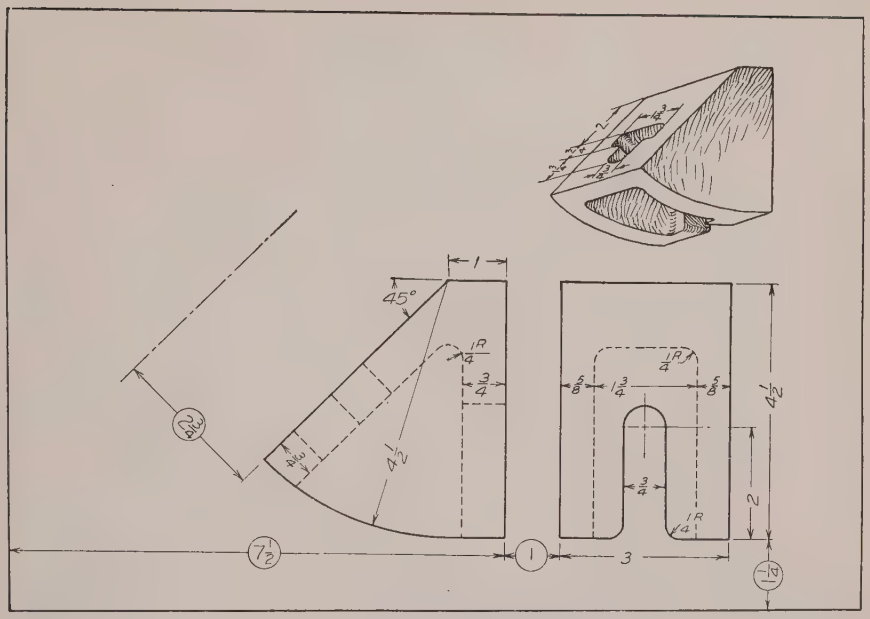


FIG. 440.—Prob. 138. Angle support.

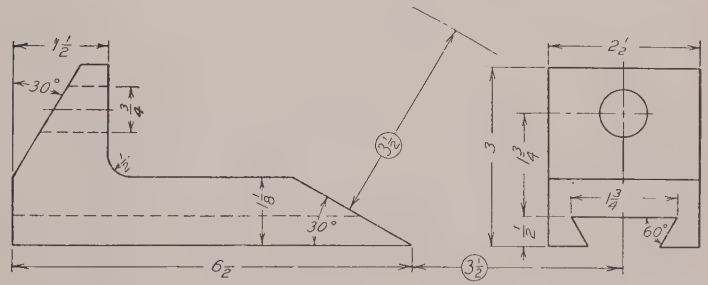


FIG. 441.—Prob. 139. Sloping dovetail.

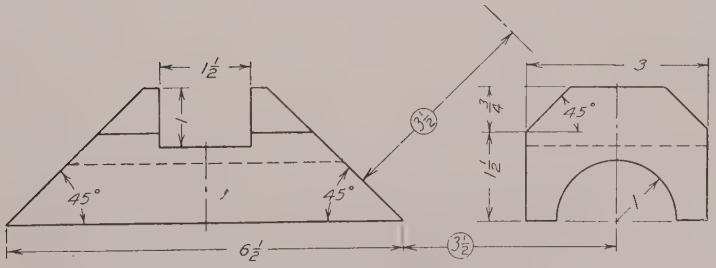


FIG. 442.—Prob. 140. Shaft holder.

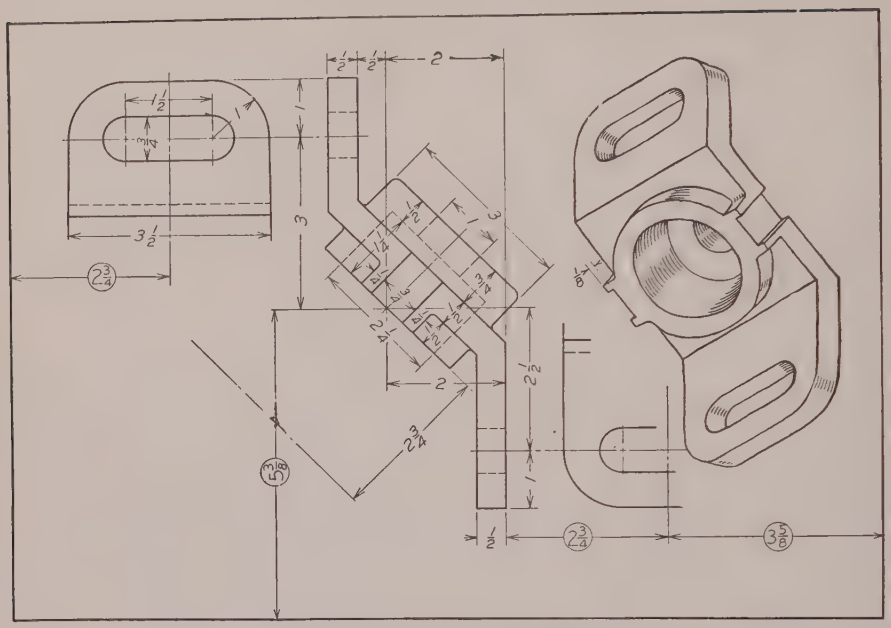


FIG. 443.—Prob. 141. Inclined stop.

The layout given in Fig. 444 is designed for use with Probs. 139 and 140 as well as Prob. 142.

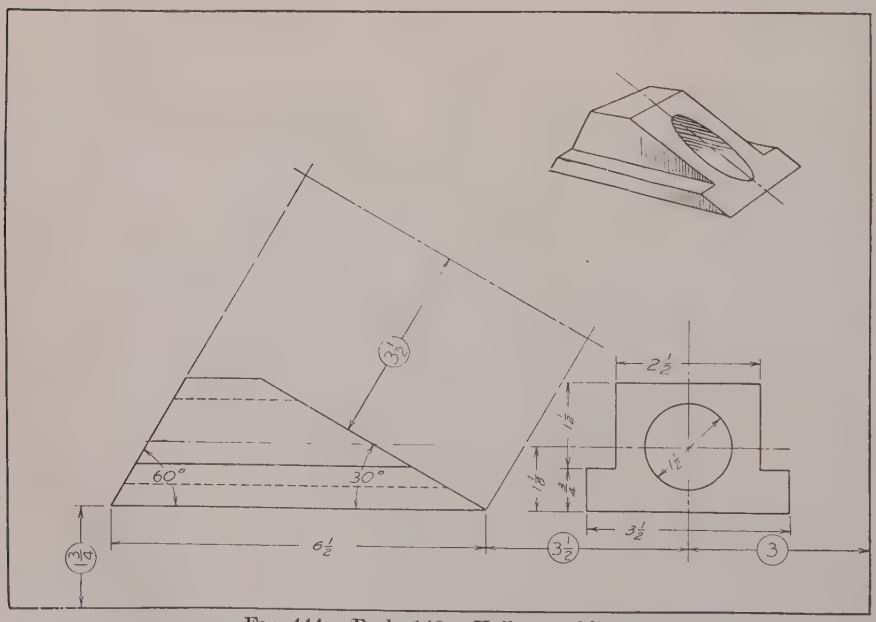


FIG. 444.—Prob. 142. Hollow molding.

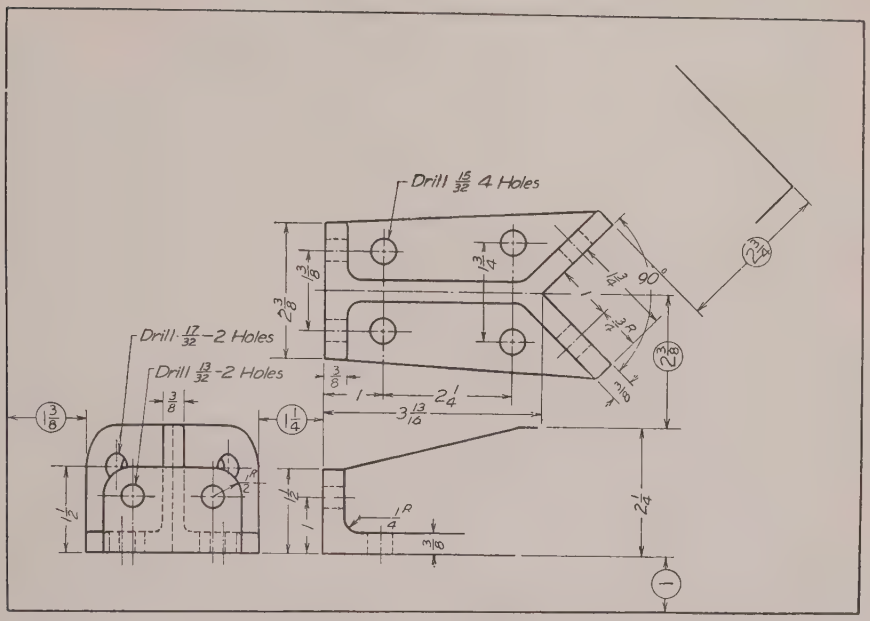


Fig. 445.—Prob. 143. Angle spacer.

Prob. 141. Figure 443 shows a picture and a layout for an **inclined stop.** The complete view in the middle of the space is the right-side view. Draw this side view. Draw the part front view shown in the upper left-hand part of the space. Draw a part rear view on both sides of the vertical center line in the lower right-hand part of the space. Draw an auxiliary view of the inclined part. Refer to Art. 51. Note that this will be a front auxiliary view made on a plane perpendicular to the side plane. See Fig. 104 and compare with your solution of the problem. Do not copy the picture. Dimension if required by the instructor.

Prob. 142. Fig. 444. A picture and a layout for a piece of **hollow molding** are shown in the figure. Consider the left-hand view to be the front view. Draw the front and side views as shown. Draw a complete auxiliary view on a plane parallel to the cut face. Refer to Art. 51. Note that this will be a right-auxiliary view made on a plane perpendicular to the vertical plane. See Fig. 103 and compare with your solution of this problem. Do not copy the picture.

Prob. 143. Fig. 445. A top view, a left-side view and an incomplete front view of an **angle spacer** are shown on the layout in the figure. Draw the top view, finish the incomplete front view and draw the side view. The invisible parts of the holes which show as ellipses in the front view and side views need not be drawn. Draw a part auxiliary view where indicated in the upper right-hand part of the space. Refer to Art. 51. Note that this will be an auxiliary elevation as it is made on a plane perpendicular to the horizontal plane. See Fig. 102 and compare with the solution of your problem. Dimension if required by the instructor.

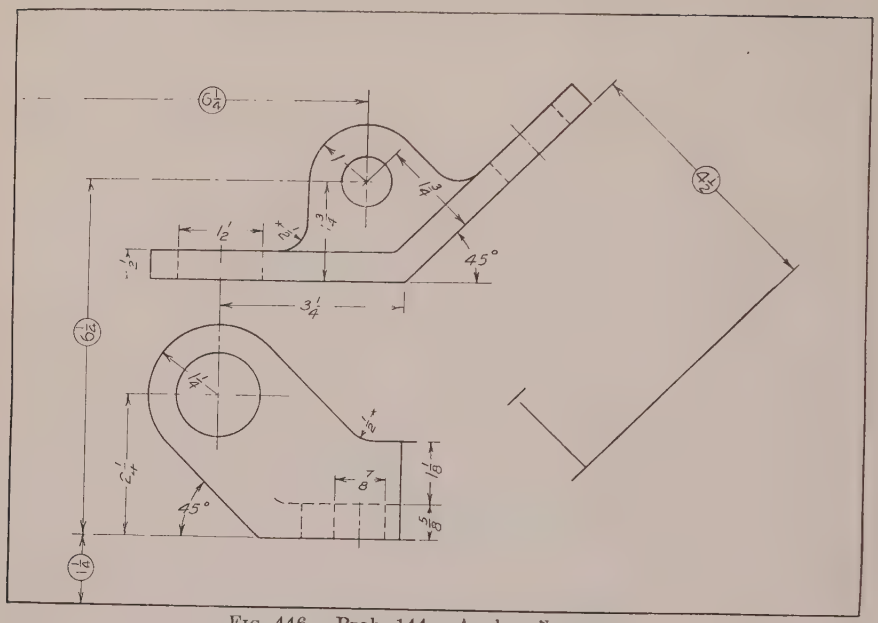


FIG. 446.—Prob. 144. Angle rail support.

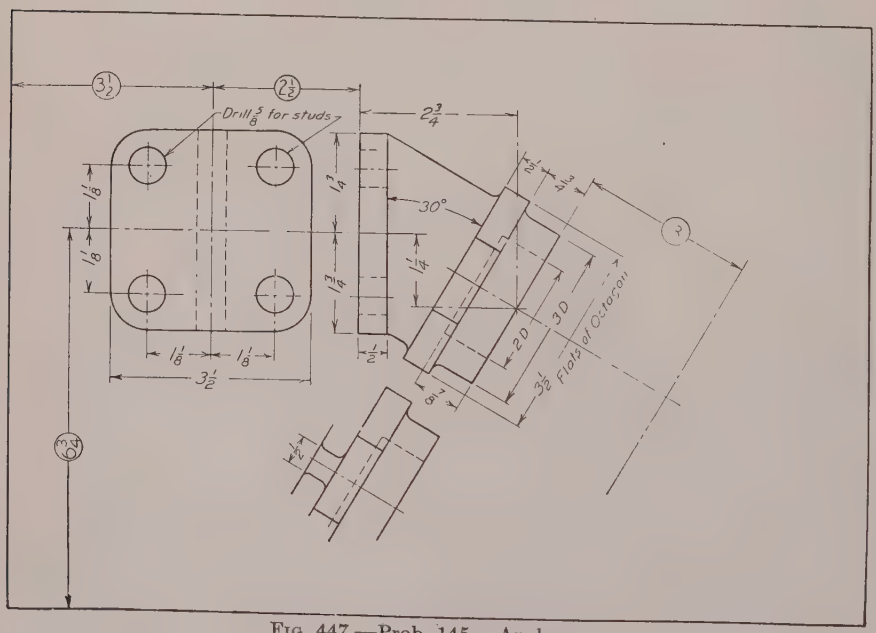


FIG. 447.—Prob. 145. Angle cap.

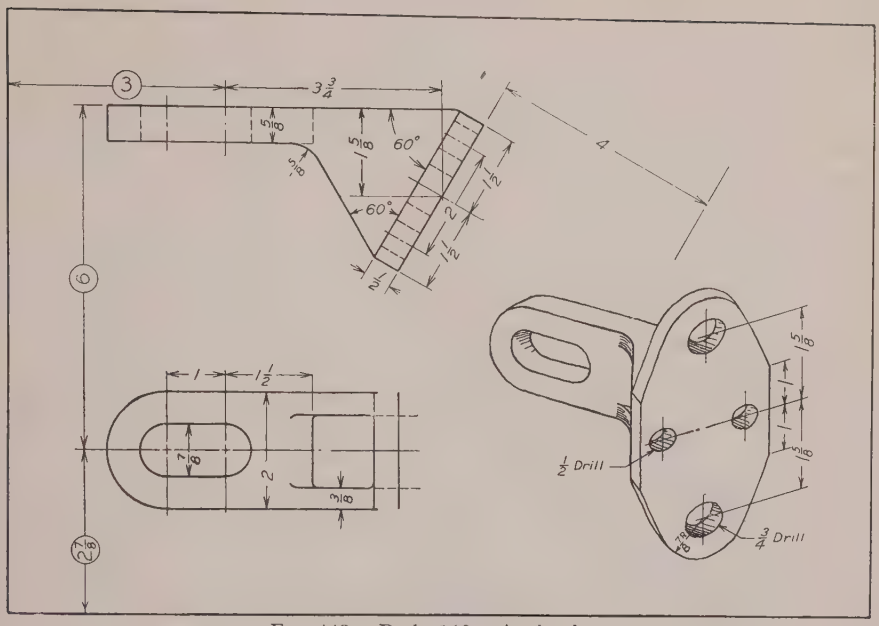


FIG. 448.—Prob. 146. Angle plate.

Prob. 144. Fig. 446. A top view and part front view of an **angle rail support** are shown in the layout in the figure. Draw the top view and the part front view as shown. Draw a part auxiliary view where indicated on the layout. Refer to Art. 51. Note that this will be an auxiliary elevation as it is made on a plane perpendicular to the horizontal plane. See Fig. 102 and compare with the solution of your problem. Dimension if required by the instructor.

Prob. 145. Fig. 447. A part front view, a right-side view and a part auxiliary view of an **angle cap** are shown on the layout in the figure. Draw the views given and another part auxiliary view where indicated on the layout. Refer to Art. 51. Note that this last auxiliary view is a rear auxiliary view and that the one shown on the layout is a front auxiliary view. See Fig. 104 and compare with the solution of your problem. Dimension if required by the instructor.

Prob. 146. Fig. 448. A picture and a layout for an **angle plate** are shown in the figure. Draw the top view and the part front view as shown. Draw a part auxiliary view where indicated on the layout. Refer to Art. 51. Note that this is an auxiliary elevation as it is made on a plane perpendicular to the horizontal plane. See Fig. 102 and compare with the solution of your problem. Do not copy the picture. Dimension if required by the instructor.

Group VII. Revolutions.

232. Study Arts. 54 to 59 and understand the rule of revolution as there explained before beginning the problems in this group. The object of including one or two problems in revolution in a course in drawing, when time permits, is to give further training in the relationship of views.

Prob. 147. Fig. 449. The figure shows the completed problem. It is given for comparison and is not to be copied. Divide the standard sheet into four equal parts. In the first space is a three-view drawing of a block in its simplest position. In space two (upper right hand) the block is shown after being revolved from the position in space one, through 45°, about an axis perpendicular to the vertical plane. The front view was drawn first, copying the front view of space one, and the top view obtained by projecting up from the front view and across from the top view in space one.

In space three (lower left hand) the block has been revolved from position one through 30° about an axis perpendicular to the horizontal plane. The top view was drawn first, copied from the top view of space one. In space four, the block has been tilted forward from position two about an axis perpendicular to the side plane. The side view was drawn first, copied from the side view of space two, and the widths of front and top view projected from the front view of space two.

A convenient method of obtaining the widths of the side views by "mitering" from the top view is shown in Fig. 449.

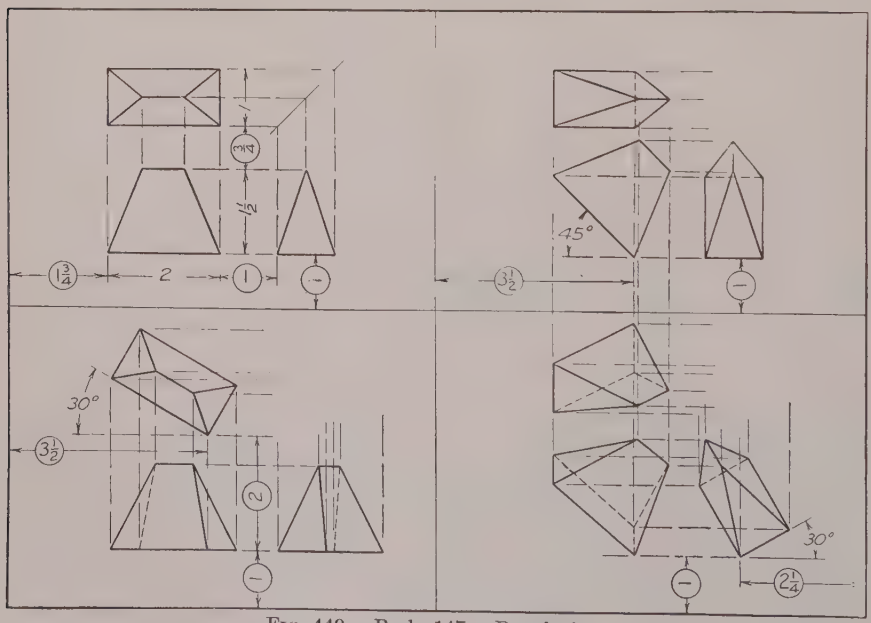


FIG. 449.—Prob. 147. Revolution.

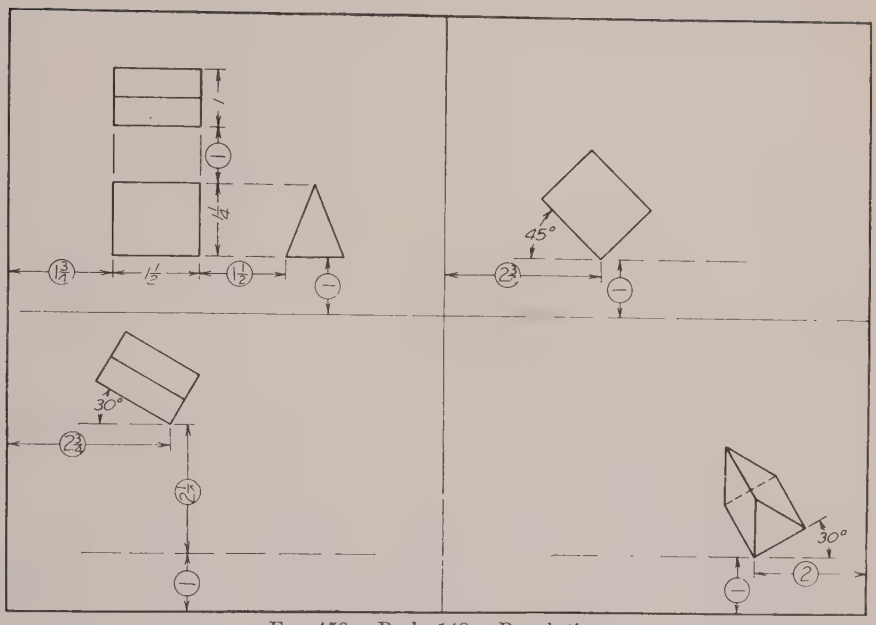
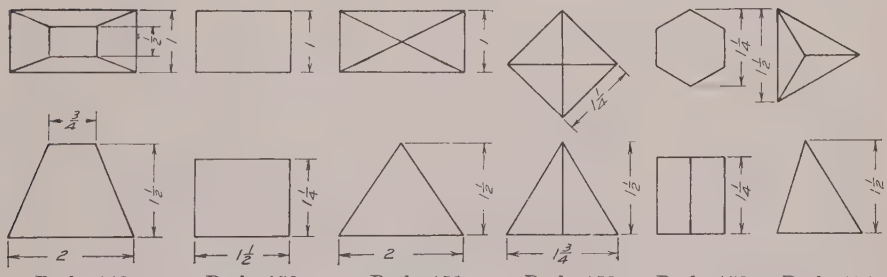


FIG. 450.—Prob. 148. Revolution.



Prob. 149. Prob. 150. Prob. 151. Prob. 152. Prob. 153. Prob. 154.

FIG. 451.—Probs. 149, 150, 151, 152, 153, 154.

Prob. 148. Fig. 450. Divide the sheet into four equal parts. In space one (upper left-hand) draw three views of the wedge as shown. In spaces two, three and four revolve it in the same way as was done in the corresponding spaces of Fig. 449. Follow the directions as given for Prob. 147 and work out the required three views of the wedge in each of the spaces.

Probs. 149, 150, 151, 152, 153, 154. Fig. 451. Alternate problems. Divide the sheet into four equal parts. Follow the directions as given for Probs. 147 and 148 and work out the required three views in each of the spaces.

Group VIII. Size Description.

233. Size description, or dimensioning, is a very important part of mechanical drawing. Study Chap. VIII carefully and apply the principles described in it to the solutions of the following problems. First draw the complete views for shape description, then put on all dimension lines for size dimensions and for location dimensions. When certain that all dimensions are indicated, fill in the dimensions and add notes where necessary.

Prob. 155. Fig. 452. Three partial views of a **slide rod carrier** are given. Make a complete working drawing with all necessary dimensions. Work out the location of the views carefully (Art. 229), making allowance for the space required for the dimensions. Note the location of the finished surfaces when giving the location dimensions.

Prob. 156. Fig. 453. Make a complete three-view working drawing of the **adjustable center.** Locate the views carefully (Art. 229) making allowances for the space required for the dimensions. Note the location of the finished surfaces when giving the location dimensions.

Prob. 157. Fig. 454. Make working drawings of the **gland** and **bearing,** with complete dimensions. The diameter of the hole (1″) and of the hub (1¾″) should be added to the gland. For the bearing the distance from the underside of the base up to the center of the hole is 2″. The length of the hole is 1¾″ and its diameter is ¾″. The thickness of the base is ⅝″. Locate the views carefully (Art. 229) making allowance for the space required for dimensions. Note the location of the finished surfaces when giving the location dimensions.

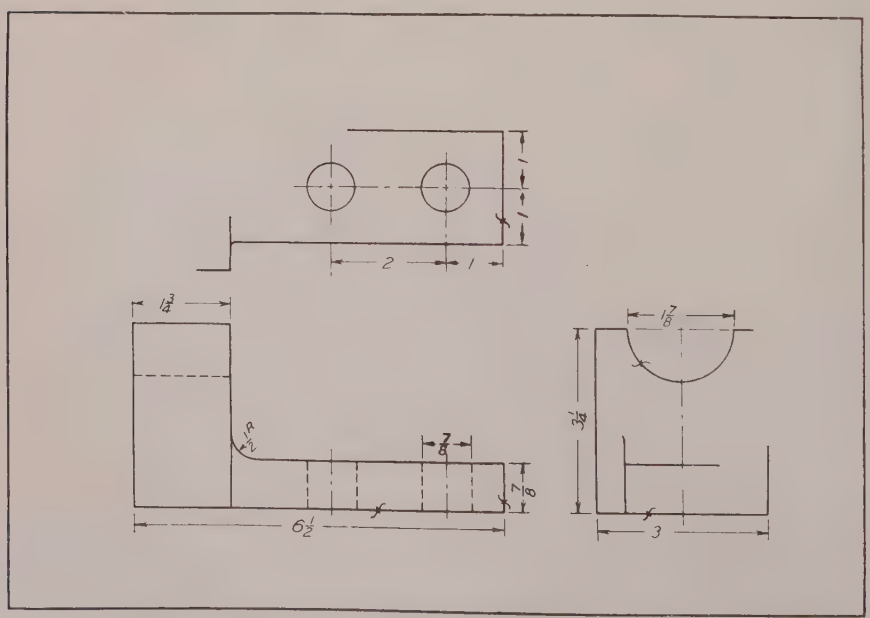


Fig. 452.—Prob. 155. Slide rod carrier.

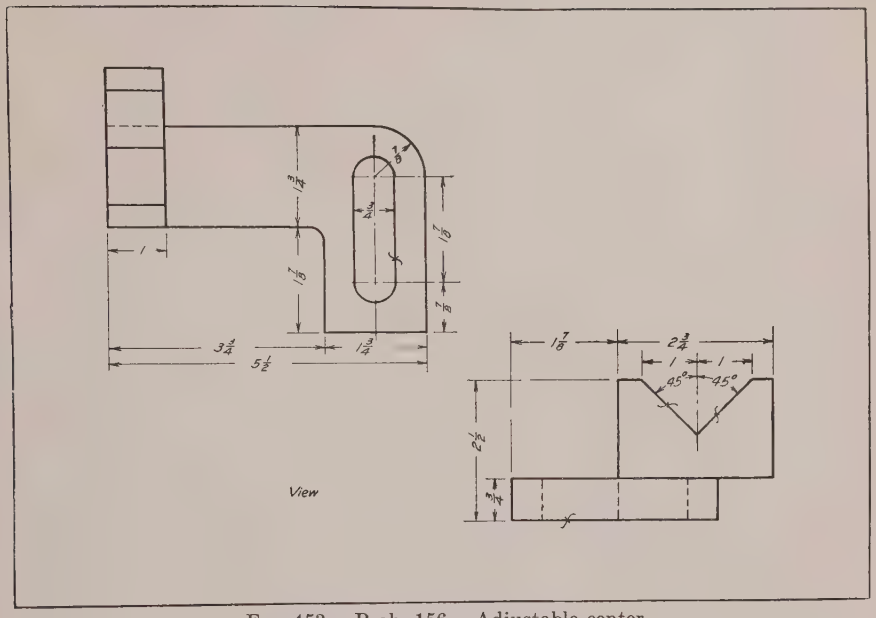


FIG. 453.—Prob. 156. Adjustable center.

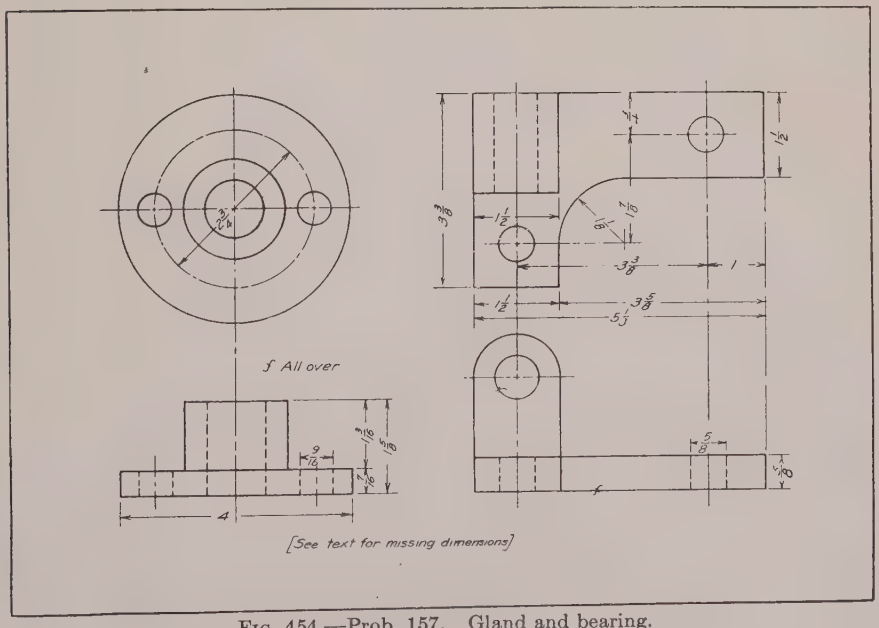


FIG. 454.—Prob. 157. Gland and bearing.

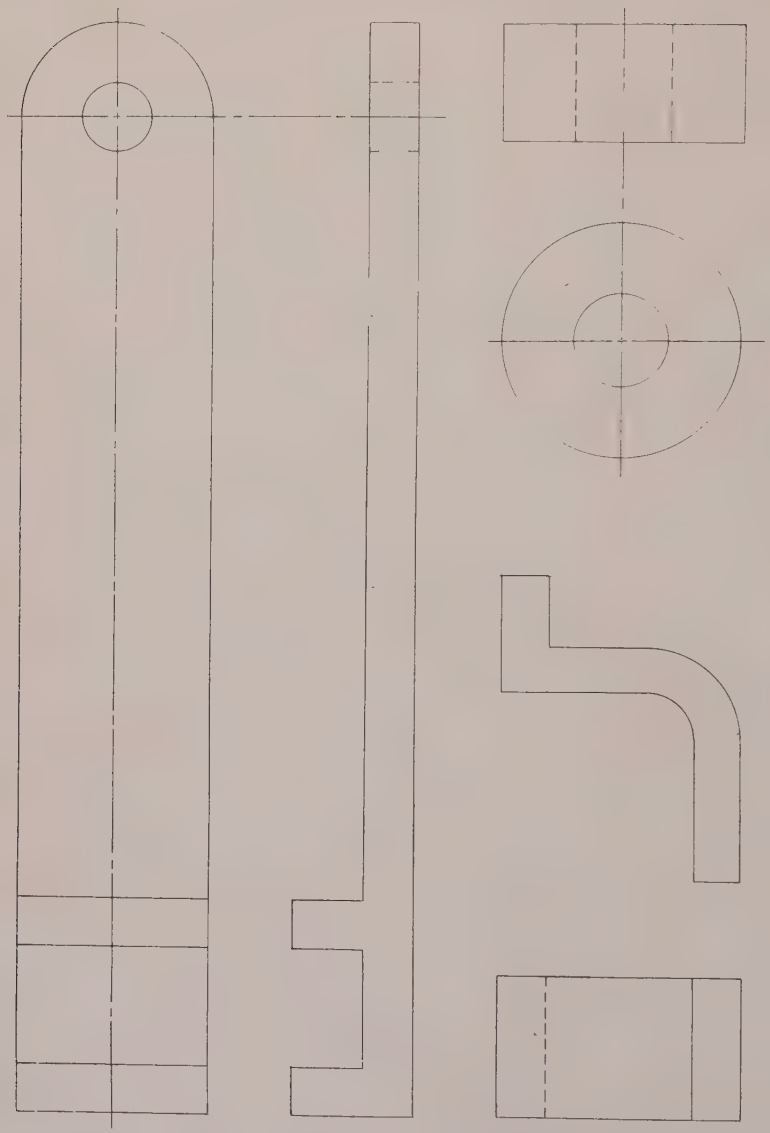


Fig. 455.—Prob. 158. Dimensioning studies.

Prob. 158. Fig. 455. This page is half size. Using the right hand of the figure as the bottom of the sheet, make a full-sized working drawing, transferring the views by using either dividers or the scale, and dimension it completely, obtaining dimensions by measuring your drawing.

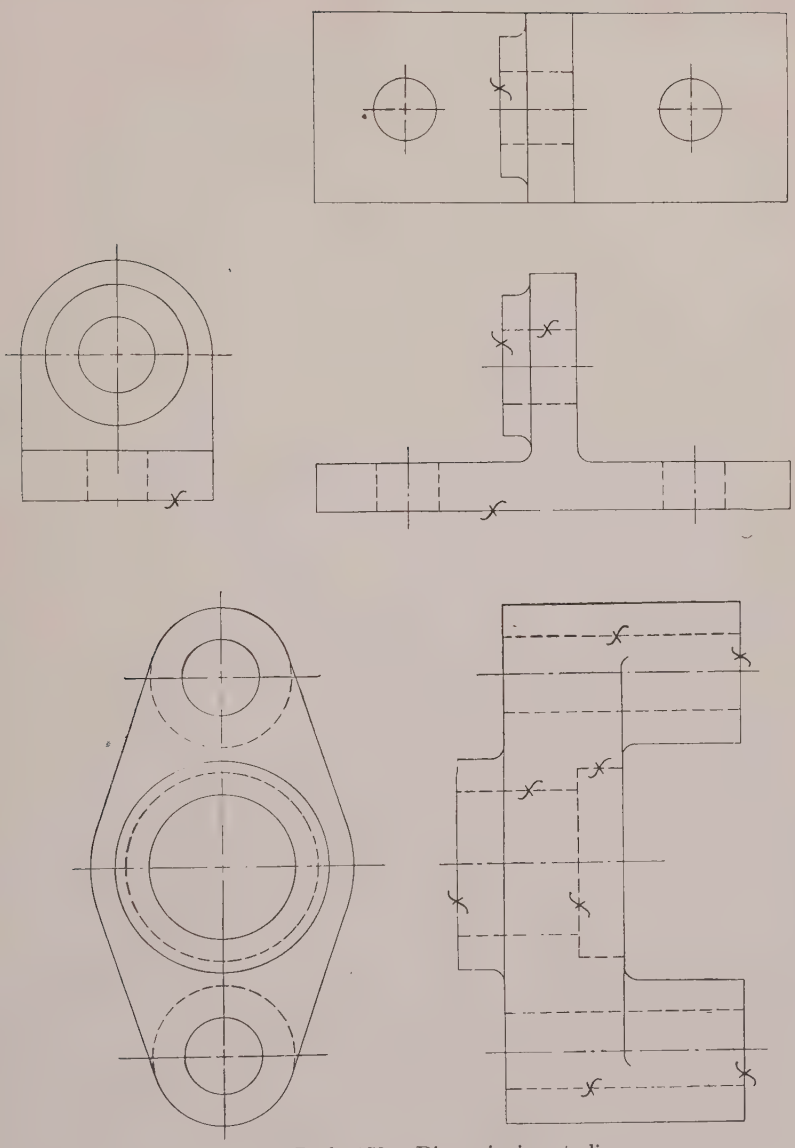


Fig. 456.—Prob. 159. Dimensioning studies.

Prob. 159. Fig. 456. Copy the views to twice the size in the book. Use the right-hand side of the figure as the bottom of the sheet. Completely dimension the pieces, obtaining dimensions by scaling your drawing.

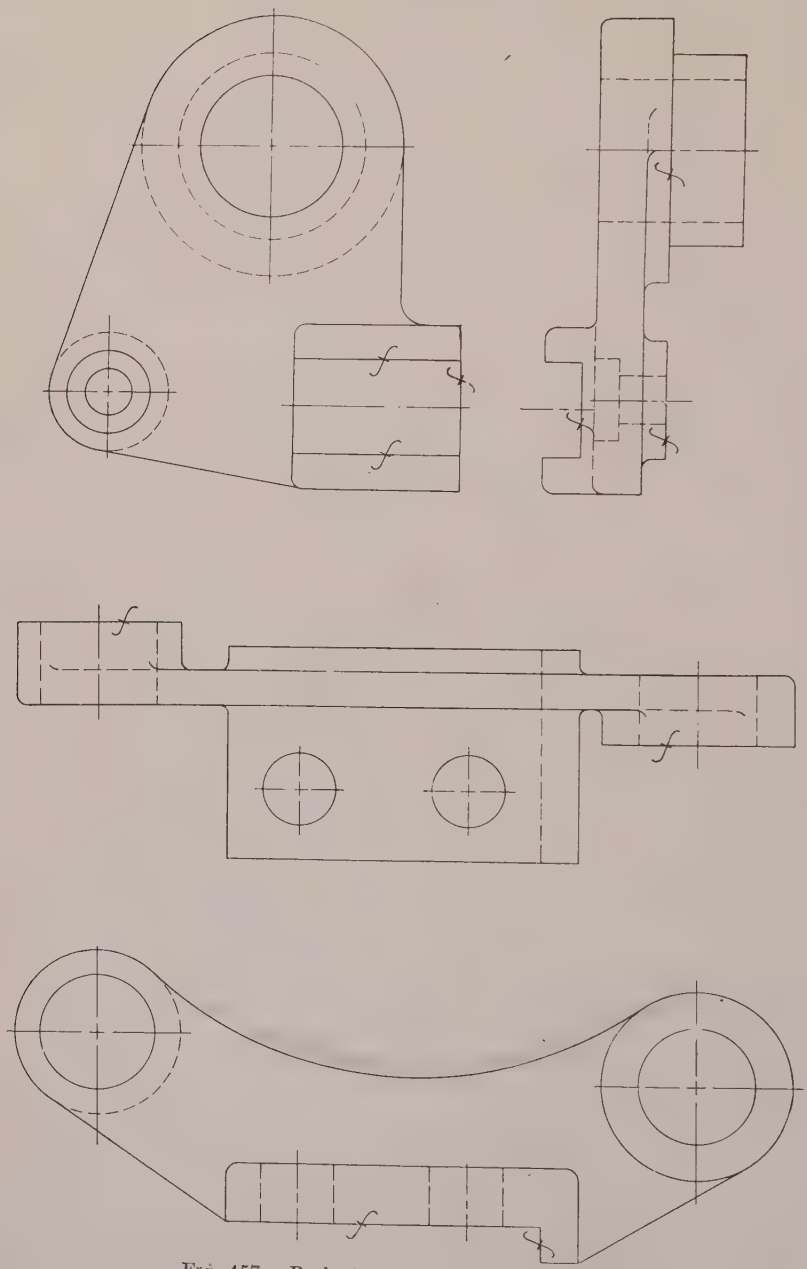


FIG. 457.—Prob. 160. Dimensioning studies.

Prob. 160. Fig. 457. Copy the views to twice the size in the book. Use the right-hand side of the figure as the bottom of the sheet. Completely dimension the pieces, obtaining dimensions by scaling your drawing.

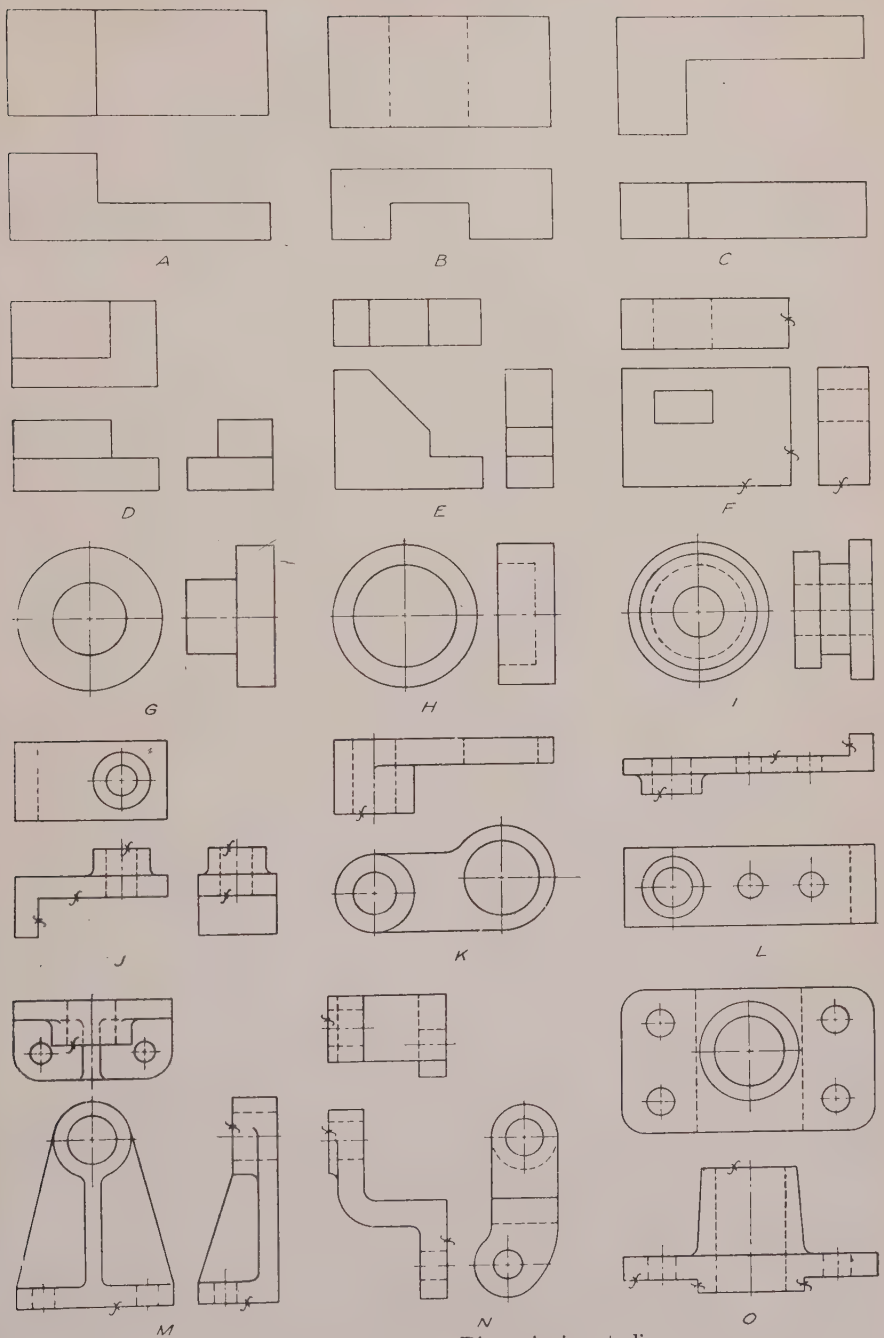


FIG. 458.—Prob. 161. Dimensioning studies.

Prob. 161. Fig. 458. Copy the views freehand, enlarged. Add dimensions, using S for size dimensions and L for location dimensions.

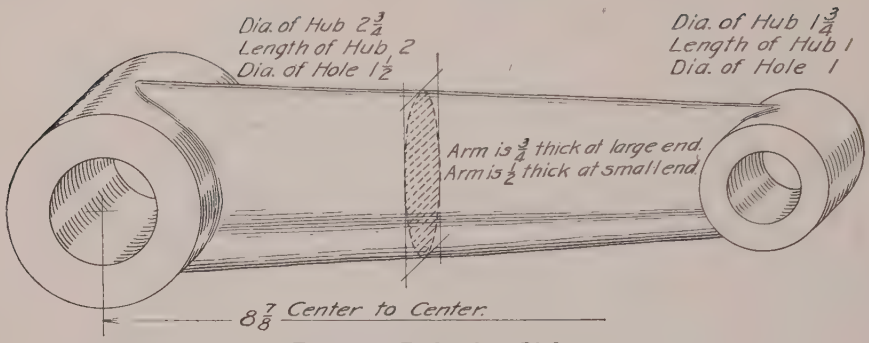

Dia. of Hub 2 3/4
Length of Hub 2
Dia. of Hole 1 1/2
Dia. of Hub 1 3/4
Length of Hub 1
Dia. of Hole 1
Arm is 3/4 thick at large end.
Arm is 1/2 thick at small end
8 7/8 Center to Center

FIG. 459.—Prob. 162. Link.

Prob. 162. Fig. 459. Make a complete working drawing of the **link,** with dimension lines, extension lines and dimensions correctly placed. Do not copy the notes or dimensions as given in the picture. Fig. 460 gives the layout for the problem.

Prob. 163. Fig. 461. Make a complete working drawing of the **bell crank** with dimensions placed correctly. Do not copy the notes from the picture. Fig. 462 gives the layout for the problem.

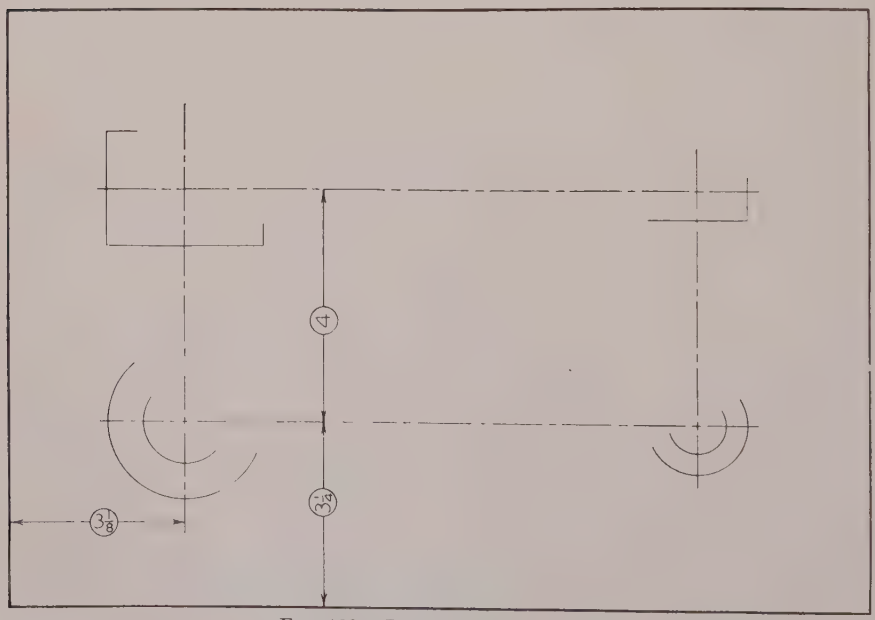


FIG. 460.—Layout for Prob. 162.

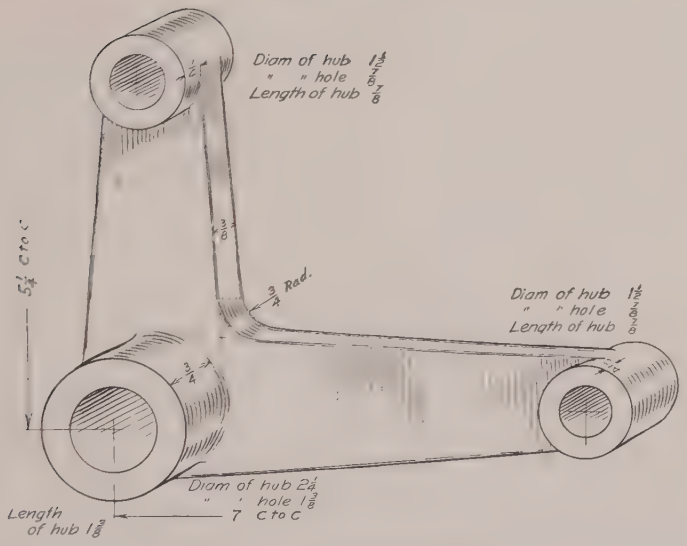

Diam of hub 1 1/2
" " hole 3/8
Length of hub 7/8
5 1/4 C to C
3/4 Rad.
Diam of hub 1 1/2
" " hole 3/8
Length of hub 7/8
3/4
Diam of hub 2 1/4
" " hole 1 3/8
Length of hub 1 3/8
7 C to C

FIG. 461.—Prob. 163. Bell crank.

In the layout of Fig. 462 note that a complete front view is suggested with a view at the left to show the vertical arm, and a part top view of the horizontal arm.

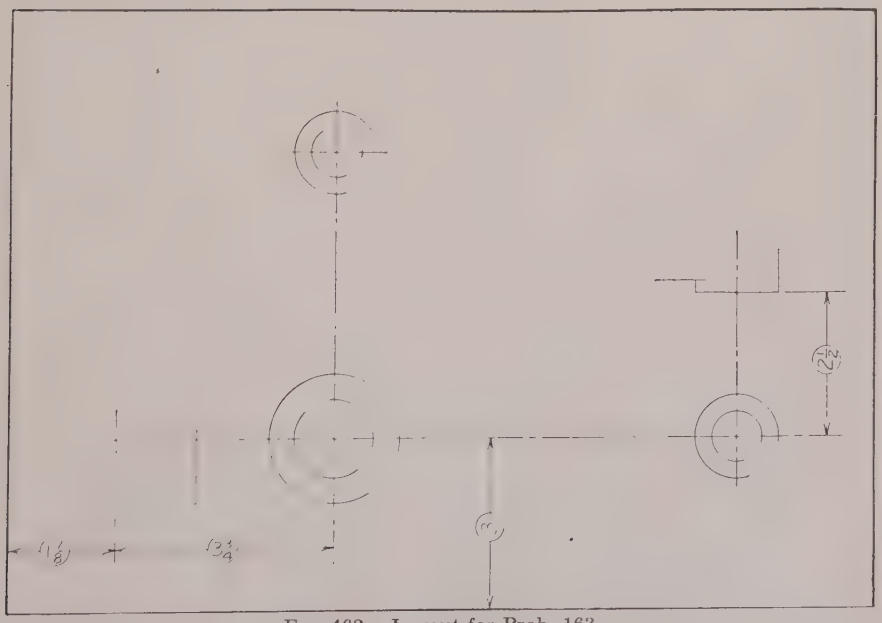


FIG. 462.—Layout for Prob. 163.

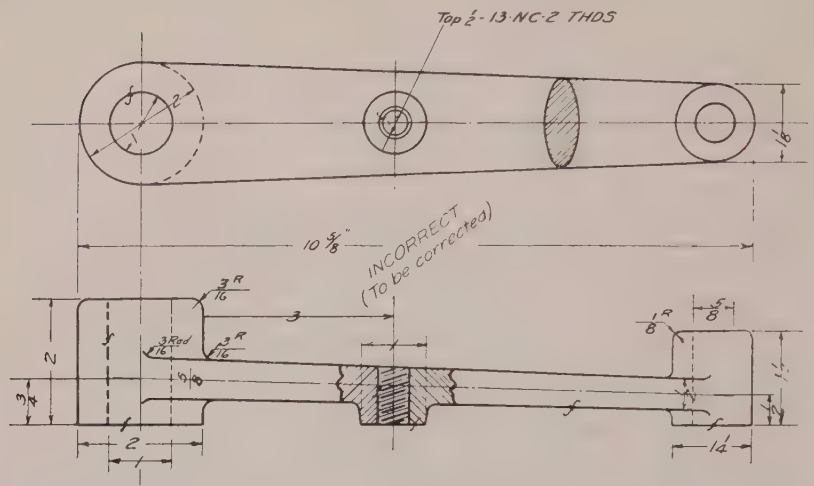


FIG. 463.—Prob. 164. An incorrect drawing to be checked and redrawn (link).

Prob. 164. Fig. 463. This problem is for practice in checking a drawing. The views as drawn contain many mistakes and represent a very poor drawing. Check the views carefully, and then redraw them correctly (compare Figs. 139 and 140).

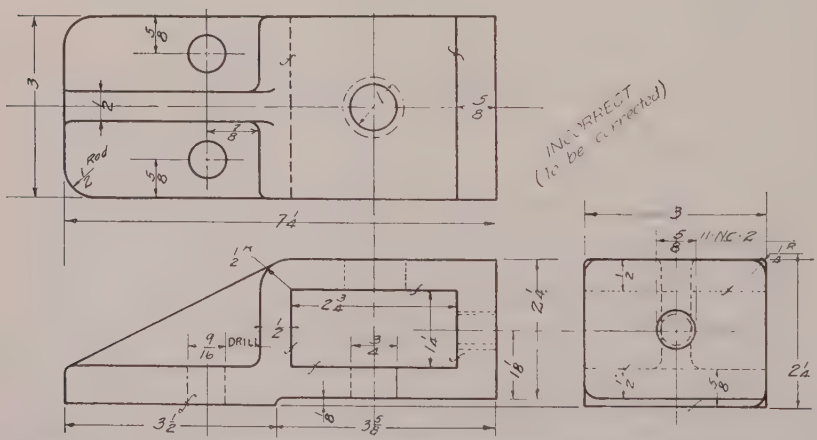


FIG. 464.—Prob. 165. An incorrect drawing to be checked and redrawn (swivel base).

Prob. 165. Fig. 464. This problem is for practice in checking a drawing. The views as drawn contain many mistakes and represent a very poor drawing. Check the views carefully, and then redraw them correctly (compare Figs. 139 and 140).

Group IX. Bolts and Screws.

231. It is necessary for a draftsman to know the forms of screw threads and the conventional methods of drawing bolts and screws. Read Chap. X carefully before starting the problems in this group. Threads are always understood to be single and right hand unless otherwise specified. A right-hand thread enters when turned clockwise. A left-hand thread enters when turned counterclockwise and is always marked L.H. on a drawing. When the American Standard form and number of threads per inch are used, it is not necessary to specify except by a note. Table I gives screw-thread information.

Prob. 166. Fig. 465. In the left half of the sheet construct two complete turns of a right-hand helix whose diameter is 4″ and pitch 1½″ (Arts. 88 and 89). In the right half of the sheet draw, as shown in the layout, the forms of the *V* thread, American Standard thread and square thread, each with 1″ pitch. Letter the name of each form under the drawing of it.

Sometimes in drawing a helix a templet is made by laying out the curve on a piece of cardboard, celluloid or thin wood and cutting out with a sharp knife.

Prob. 167. An alternate for Prob. 166. In the left half of the sheet construct two complete turns of a right-hand helix whose diameter is 3″ and pitch 2″. In the right half draw the forms of the American Standard thread, Acme thread and knuckle thread, each with 1″ pitch. Letter the name of each form under the drawing of it.

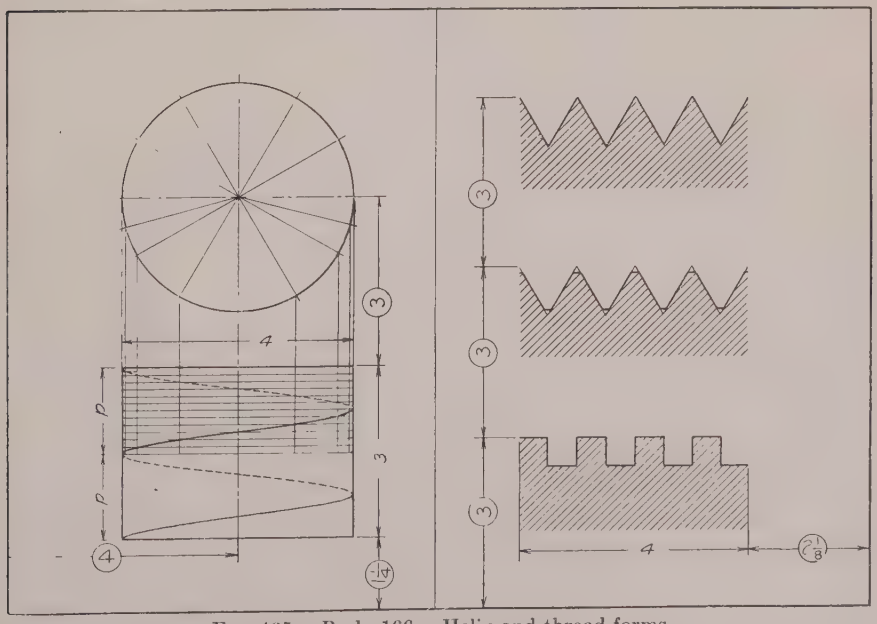


FIG. 465.—Prob. 166. Helix and thread forms.

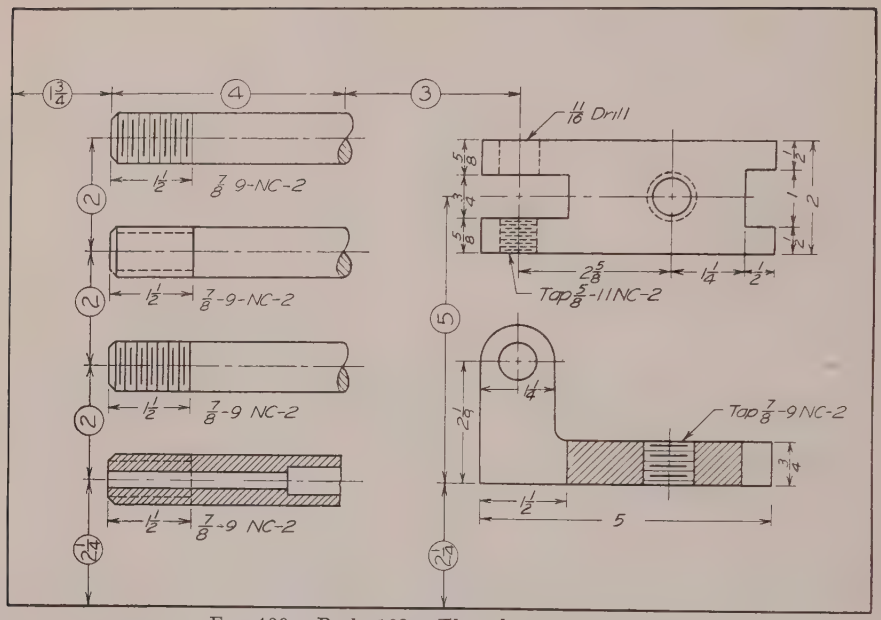


Fig. 466.—Prob. 168. Thread representations.

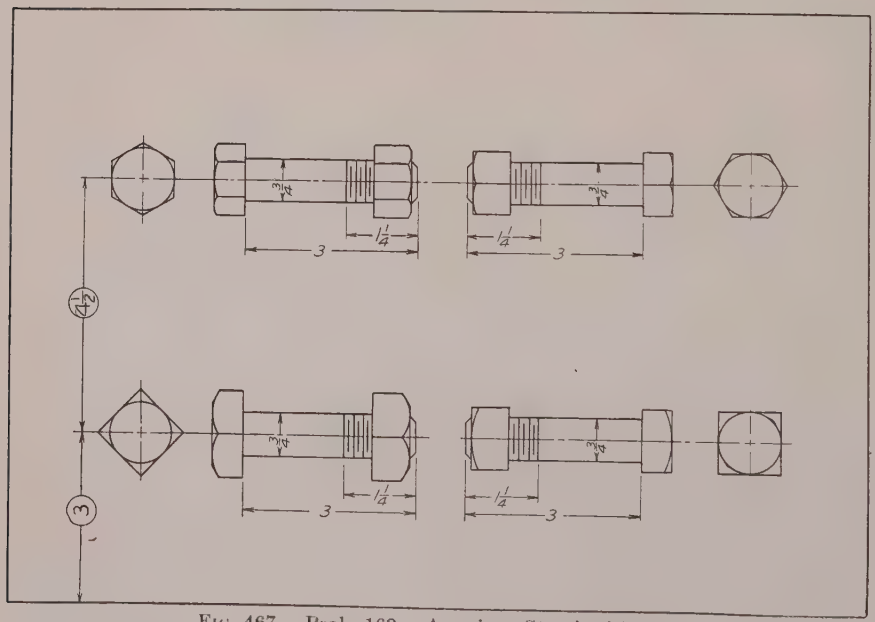


Fig. 467.—Prob. 169. American Standard bolts.

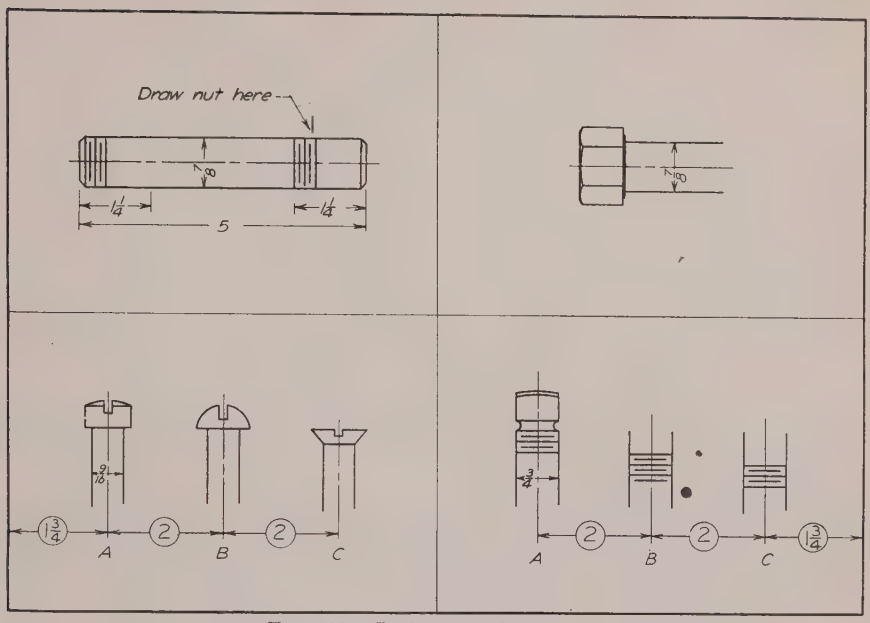


FIG. 468.—Prob. 170. Fastenings.

Prob. 168. Fig. 466. Locate center lines as shown and draw the conventional thread representations given in the layout. These and several other conventional forms are in use for representing screw threads and are drawn here for practice. On working drawings one of the forms should be selected and used for all thread representations. The casting drawn on the right half of the sheet has threaded holes represented conventionally under three different conditions.

Prob. 169. Fig. 467. Locate the center lines. On the upper line draw an American Standard hexagonal-head bolt and nut in the two positions shown, across corners and across flats. On the lower line draw a square-head bolt and nut across corners and across flats.

Prob. 170. Fig. 468. Divide working space into four spaces as shown. In the upper left-hand space draw a stud and American Standard nut. Diameter, $\frac{7}{8}''$; length $5''$; length of thread on each end $1\frac{1}{4}''$. In the upper right-hand space drawn an American Standard hexagonal-head cap screw. Diameter, $\frac{7}{8}''$; length $2\frac{1}{4}''$. In lower left-hand space draw three forms of cap screws, at *A*, *B* and *C*. Diameter, $\frac{9}{16}''$; length $1\frac{1}{2}''$. In lower right-hand space draw three set screws, American Standard square head and two headless set screws. Diameter, $\frac{3}{4}''$; length $1\frac{1}{2}''$.

Group X. Working Drawings.

235. Study Chaps. VIII and XI very carefully before starting these problems. Use a definite system. Visualize the shape clearly and locate the views carefully to allow for the proper placing of dimensions. Use your judgment in selecting the proper scale for the drawing. Complete the views before putting on the dimension lines. Then put in all the dimension lines and fill in the dimensions. Add any necessary notes and finally check your drawing.

Group X consists for the most part of detail working drawings of separate pieces.

Many of the problems in Group IV on Shape Description, Group V on Sections, and Group VI on Auxiliary Views may be used as working drawings by adding dimensions and notes.

The wood constructions and furniture drawings of Group XI comprise an important class of working drawings. These are generally worked up as assembly drawings to which are added such details as may be necessary.

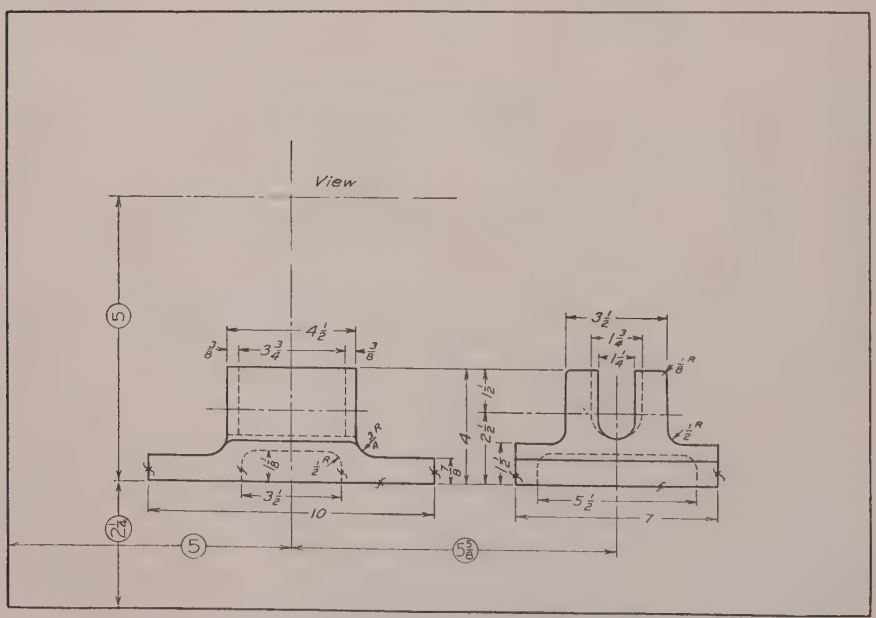


FIG. 469.—Prob. 171. Slide valve.

Prob. 171. Fig. 469. Make a three-view working drawing of the **slide valve,** showing the front view as a section. Completely dimension the drawing. Material is cast iron. Add notes where necessary and a suitable title.

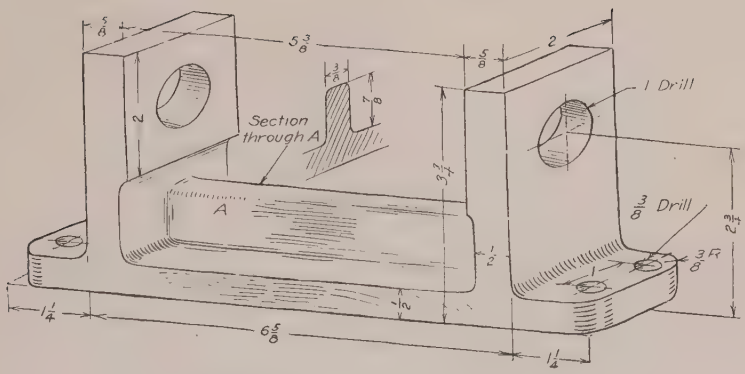


Fig. 470.—Prob. 172. Support.

Prob. 172. Fig. 470. Make a complete working drawing of the **support.** Dimension correctly, supplying missing dimensions. Indicate the surfaces which you assume to be finished. The choice and treatment of views should be considered before starting the drawing. Work out the placing of the views to allow ample room for the dimensions. See Art. 229.

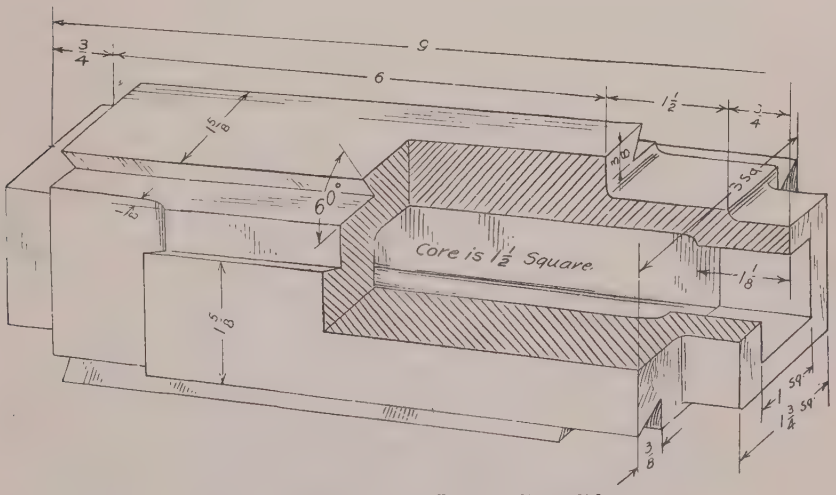
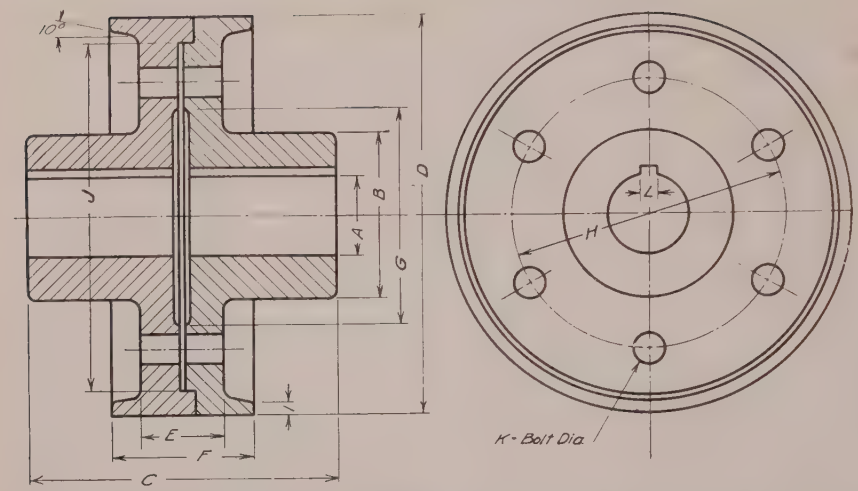


Fig. 471.—Prob. 173. Intermediate slide.

Prob. 173. Fig. 471. Make a complete working drawing of the **intermediate slide.** The broken-out section to show the internal construction is not to be put on the drawing. Completely dimension the drawing. Indicate the surfaces which you assume to be finished. The choice and treatment of views should be considered before starting the drawing. Work out the placing of the views to allow ample room for the dimensions. See Art. 229.



A	B	C	D	E	F	G	H	I	J	K	L
$1\frac{3}{16}$	$2\frac{1}{2}$	$4\frac{5}{8}$	6	$1\frac{1}{4}$	$2\frac{1}{8}$	$3\frac{1}{4}$	4	$\frac{3}{16}$	$5\frac{1}{4}$	$\frac{7}{16}$	$\frac{1}{4}$
$1\frac{7}{16}$	$2\frac{7}{8}$	$5\frac{1}{8}$	$6\frac{3}{4}$	$1\frac{3}{8}$	$2\frac{1}{4}$	$3\frac{7}{8}$	$4\frac{5}{8}$	$\frac{3}{16}$	$5\frac{3}{4}$	$\frac{1}{2}$	$\frac{5}{16}$
$3\frac{11}{16}$	$6\frac{1}{2}$	10	12	$2\frac{3}{8}$	$4\frac{1}{2}$	$7\frac{1}{4}$	$8\frac{7}{8}$	$\frac{5}{16}$	$10\frac{3}{4}$	1	$\frac{1}{2}$
$3\frac{15}{16}$	7	$10\frac{5}{8}$	$12\frac{1}{2}$	$2\frac{3}{8}$	$4\frac{1}{2}$	$7\frac{1}{2}$	$9\frac{3}{8}$	$\frac{3}{8}$	$11\frac{1}{4}$	1	$\frac{9}{16}$

FIG. 472.—Probs. 174, 175, 176, 177. Flange coupling.

Probs. 174, 175, 176, 177. Fig. 472. Make a complete working drawing of one of the sizes of **flange coupling.** Choose suitable scale. Show bolts and key in position. Missing dimensions are to be supplied by the student.

Probs. 178, 179, 180. Fig. 473. Make a complete working drawing of a **cast-iron pulley,** with one view in section. Taper of arms about $\frac{1}{2}$" per foot.

Problem	*D*	*F*	*S*	*H*	*L*	*C*	*A*	*E*
178	8	$3\frac{1}{4}$	$1\frac{1}{4}$	$2\frac{3}{8}$	$2\frac{1}{2}$	$\frac{1}{32}$	$\frac{3}{4}$	$\frac{7}{16}$
179	16	$6\frac{1}{2}$	2	$3\frac{1}{4}$	4	$\frac{1}{16}$	$1\frac{1}{8}$	$\frac{9}{16}$
180	30	$8\frac{1}{2}$	$2\frac{3}{4}$	$4\frac{1}{2}$	$5\frac{1}{2}$	$\frac{3}{32}$	$1\frac{1}{2}$	$\frac{13}{16}$

Probs. 181, 182, 183, 184. Fig. 474. Make a complete working drawing of a **Babbitted bearing,** with front and side views as half sections. Missing dimensions to be supplied by the student.

Problem	*D*	*A*	*B*	*C*	*E*	*F*	*G*	*H*
181	1	$1\frac{1}{4}$	$4\frac{3}{4}$	$1\frac{3}{8}$	$2\frac{1}{2}$	$1\frac{3}{4}$	$\frac{1}{2}$	$\frac{3}{8}$
182	$1\frac{1}{2}$	$1\frac{3}{4}$	$6\frac{3}{4}$	2	$3\frac{3}{4}$	$2\frac{5}{8}$	$\frac{5}{8}$	$\frac{1}{2}$
183	2	$2\frac{1}{4}$	$8\frac{3}{4}$	$2\frac{1}{2}$	5	$3\frac{1}{2}$	$\frac{3}{4}$	$\frac{1}{2}$
184	$2\frac{1}{2}$	$2\frac{3}{4}$	$10\frac{3}{4}$	$3\frac{1}{8}$	$6\frac{1}{4}$	$4\frac{3}{8}$	$\frac{7}{8}$	$\frac{5}{8}$

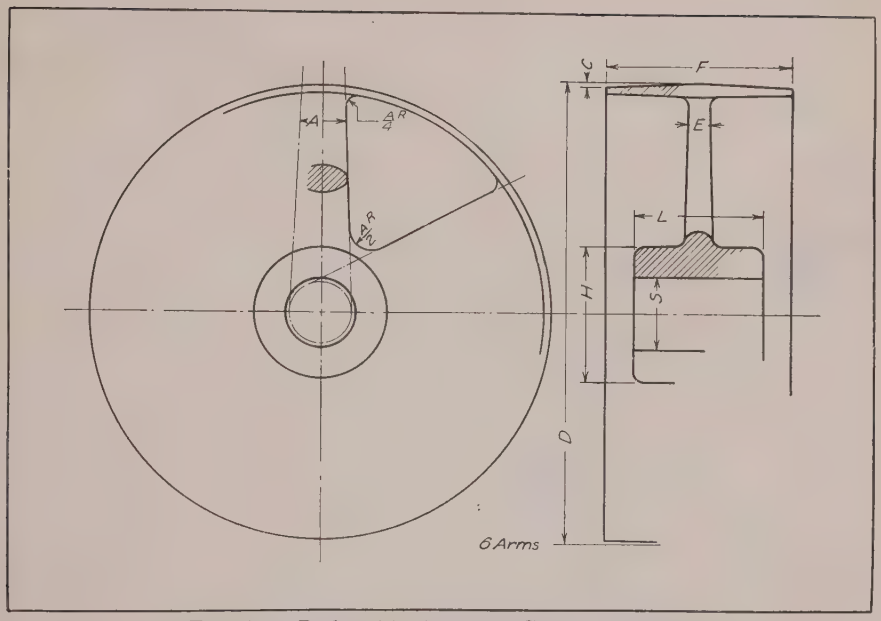


FIG. 473.—Probs. 178, 179, 180. Cast-iron pulley.

Dimensions for Probs. 178, 179, 180 are given in the table on page 234.

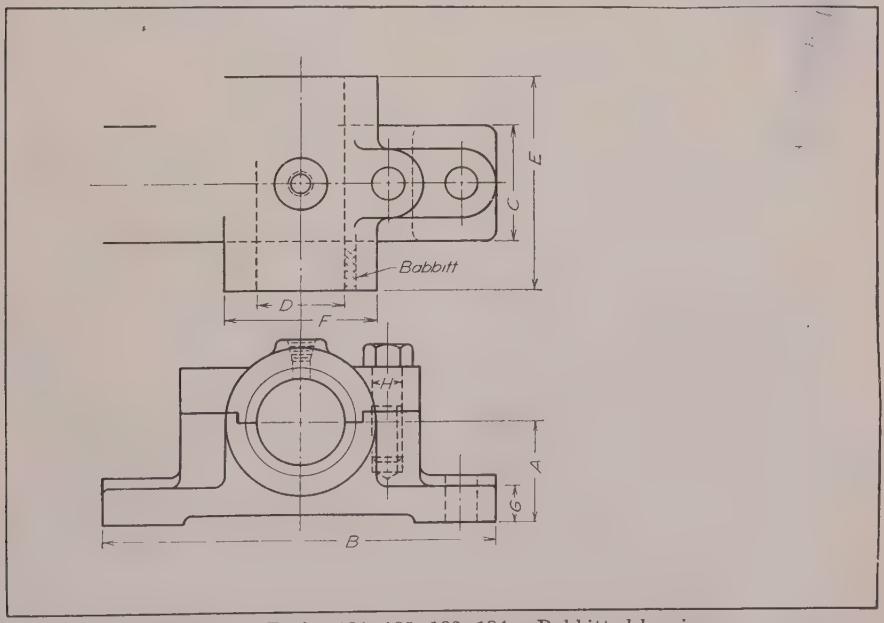


FIG. 474.—Probs. 181, 182, 183, 184. Babbitted bearing.

Dimensions for Probs. 181, 182, 183, 184 are given in the table on page 234.

Prob. 185. Fig. 475. Make a three-view working drawing completely dimensioned of the **carrier slide.** Show the front and side views as half sections. Consider the choice of views, scale and placing of views before starting the drawing.

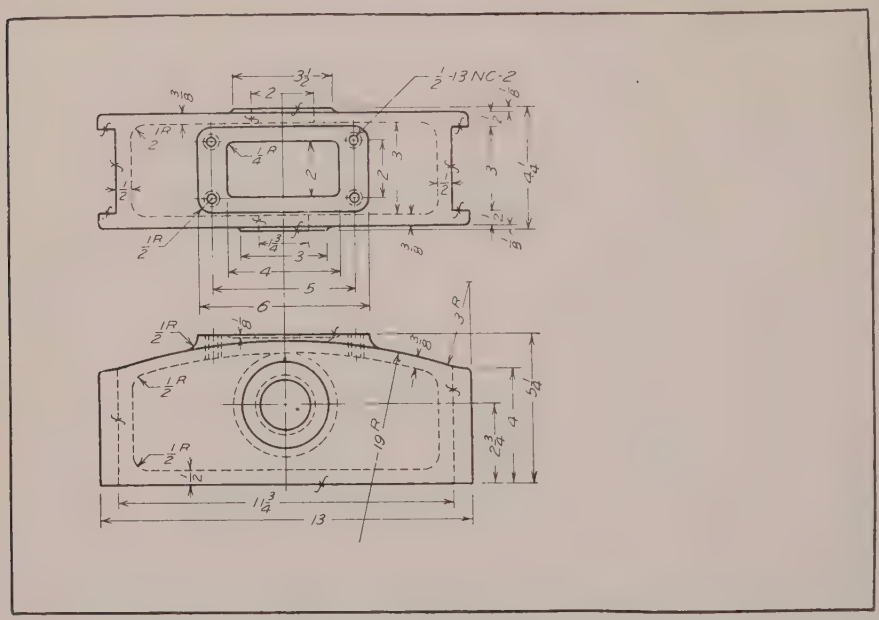


FIG. 475.—Prob. 185. Carrier slide.

Prob. 186. Fig. 476. Make a completely dimensioned two-view working drawing of the **plug wrench.** Show a revolved section through the handle. Consider the choice of views, scale, and placing of views before starting the drawing.

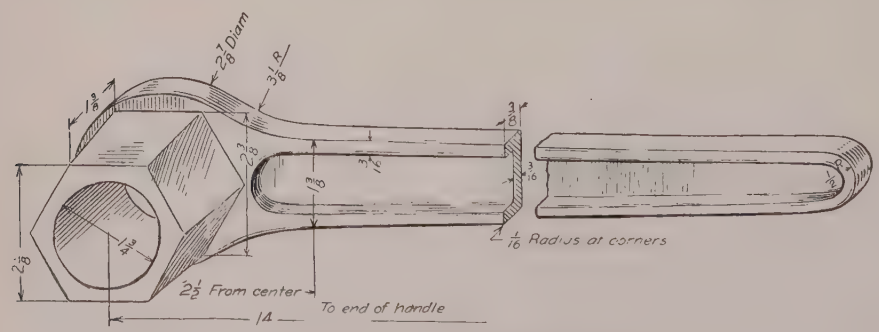


FIG. 476.—Prob. 186. Plug wrench.

Prob. 187. Fig. 477. Make a three-view working drawing, completely dimensioned, of the **bearing holder.** Consider the choice of views, scale, and placing of views before starting the drawing.

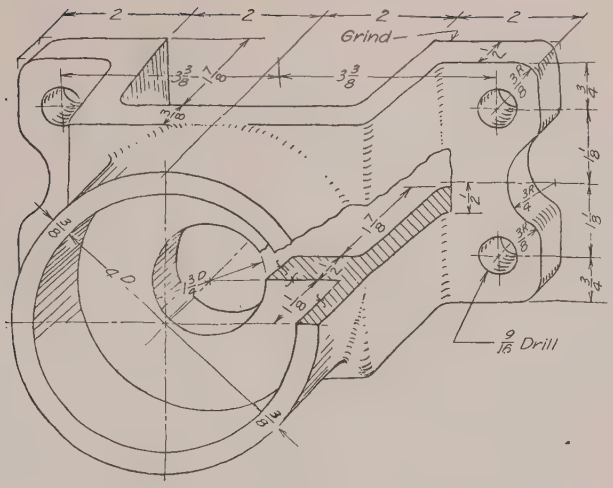


FIG. 477.—Prob. 187. Bearing holder.

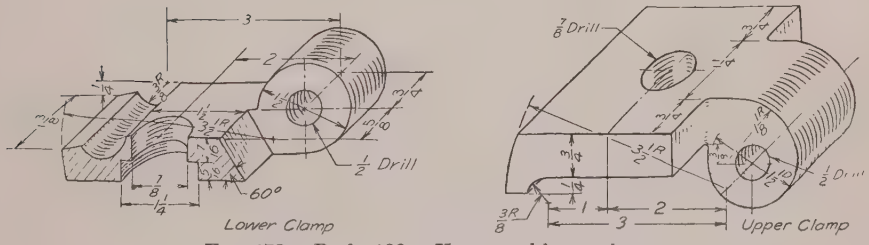


FIG. 478.—Prob. 188. Upper and lower clamps.

Prob. 188. Fig. 478. Make a working drawing showing the proper views of the **upper and lower clamps.** One-half of the lower clamp is shown in the figure. The whole clamp should be drawn. Consider the choice of views, scale, and placing of views before starting the drawing.

Prob. 189. Fig. 479. Make a two-view working drawing of the **lever** with all necessary dimensions. Use your judgment regarding finished surfaces.

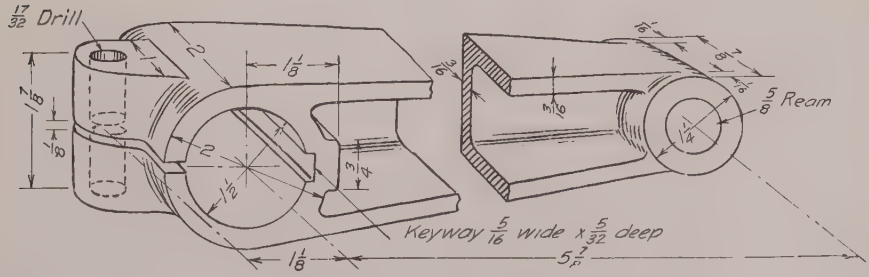


FIG. 479.—Prob. 189. Lever.

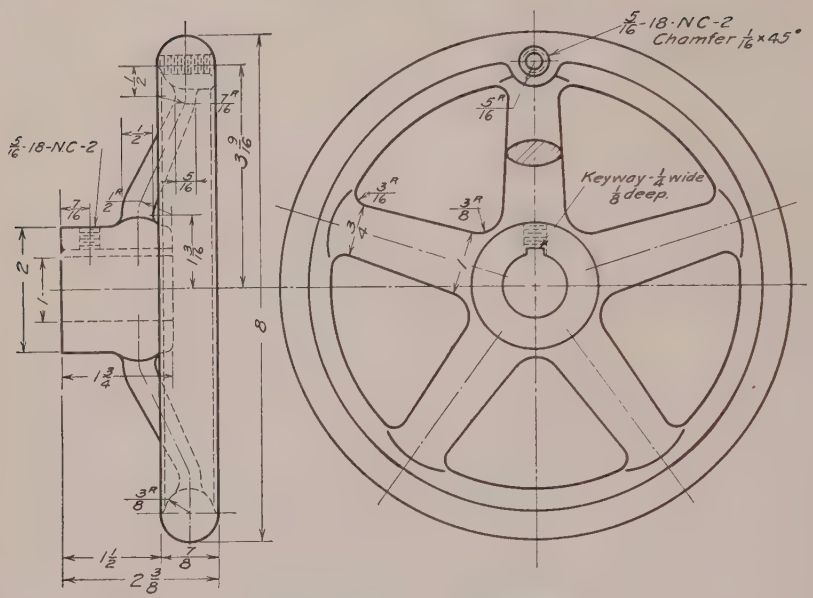


Fig. 480.—Prob. 190. Handwheel.

Prob. 190. Fig. 480. Make a two-view working drawing of the **handwheel,** showing the left view as a section. Read Art. 118 regarding arms in section. Consider choice of scale and arrangement of views before starting the drawing. Add a suitable title.

Prob. 191. Fig. 481. Make a three-view working drawing of the **center plate,** one view to be a section. Consider choice of scale and arrangement of views before starting the drawing. Add a suitable title.

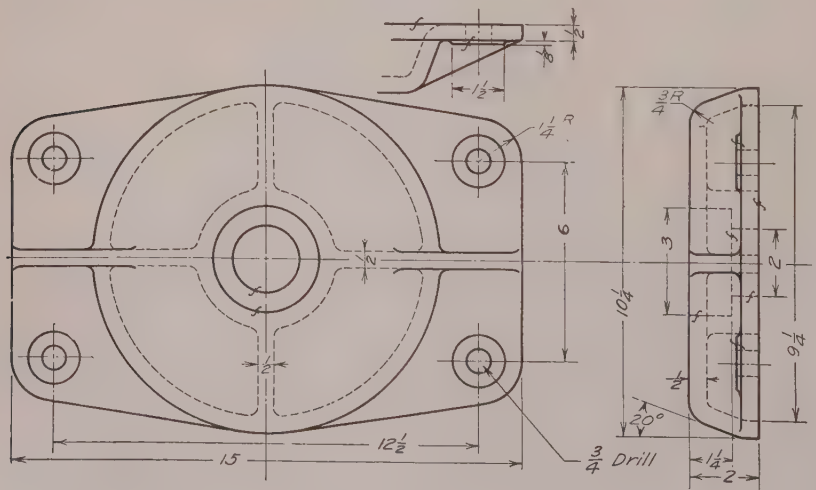


Fig. 481.—Prob. 191. Center plate.

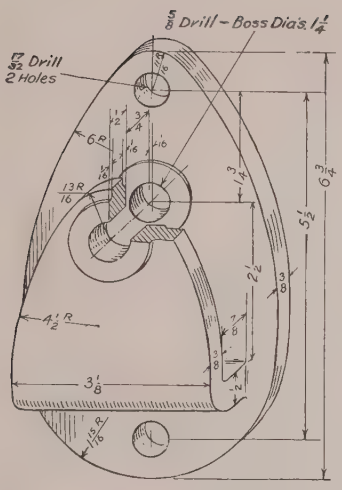


Fig. 482.—Prob. 192. Pulley bracket.

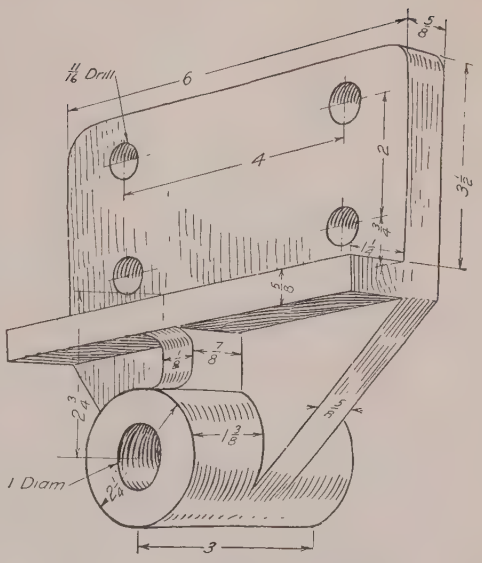


Fig. 483.—Prob. 193. Bracket bearing.

Prob. 192. Fig. 482. Make a two-view working drawing of the **pulley bracket.**

Prob. 193. Fig. 483. Make a working drawing of the **bracket bearing.**

Prob. 194. Fig. 484. Make a working drawing of the **lift-screw bracket.**

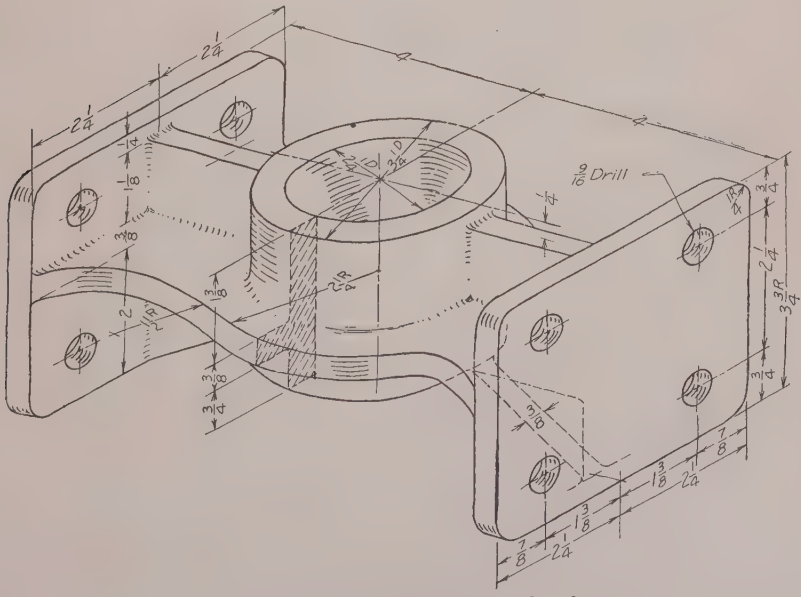


Fig. 484.—Prob. 194. Lift-screw bracket.

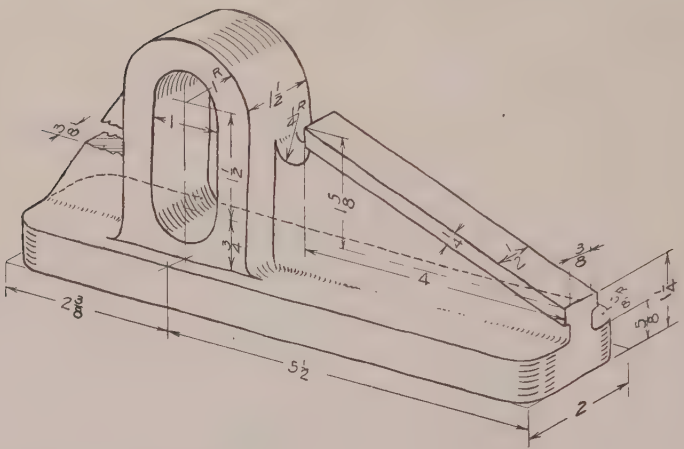


FIG. 485.—Prob. 195. Adjusting slide.

Prob. 195. Fig. 485. Make a working drawing of the **adjusting slide.** Consider the choice of views and the scale. Work out the spacing of the views to allow ample room for dimensions and notes. Indicate the surfaces which you assume to be finished. Add a suitable title.

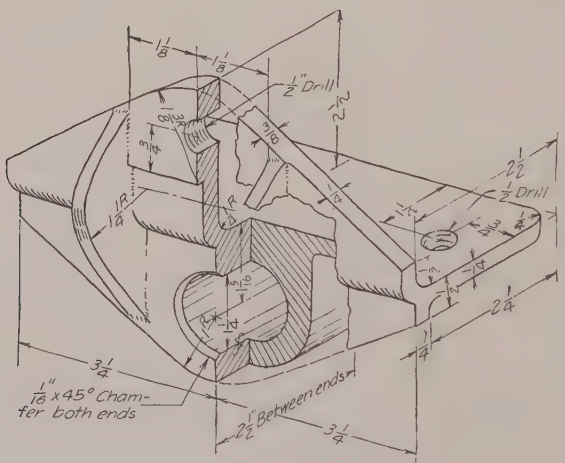


FIG. 486.—Prob. 196. Angle bearing.

Prob. 196. Fig. 486. Make a working drawing of the **angle bearing.** This object is symmetrical, but a part is broken away in the picture in order to show the interior. Consider the choice of views, the treatment of views and the scale. Work out the spacing of the views to allow ample room for dimensions and notes. Indicate the surfaces which you assume to be finished. Add a suitable title.

Group XI. Wood Constructions and Furniture Drawings.

Prob. 197. Fig. 487. Make a working drawing with complete dimensions for the **bench hook.**

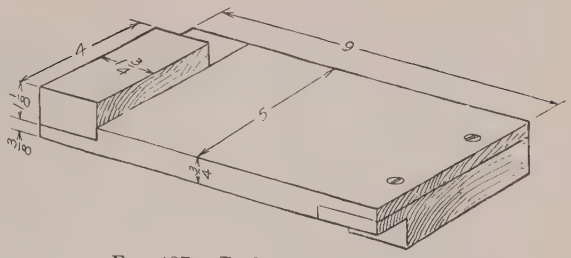


FIG. 487.—Prob. 197. Bench hook.

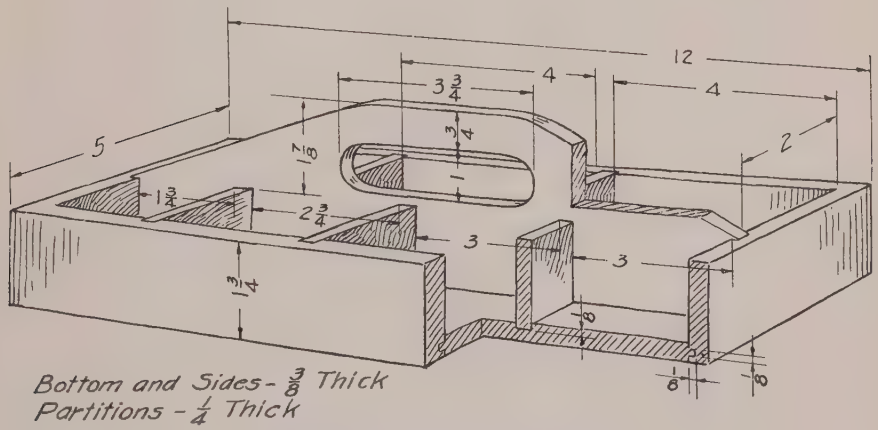


FIG. 488.—Prob. 198. Nail box.

Prob. 198. Fig. 488. Make a working drawing of the **nail box.**

Prob. 199. Fig. 489. Make a working drawing of the **sawhorse.** Use scale of 3″ = 1′.

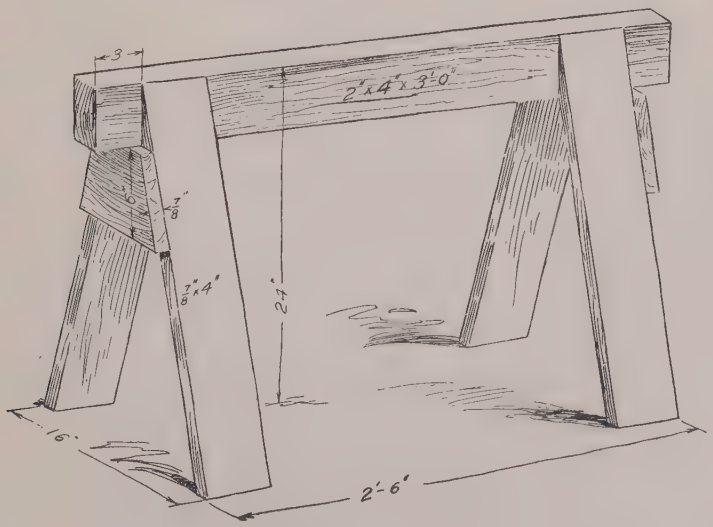


FIG. 489.—Prob. 199. Sawhorse.

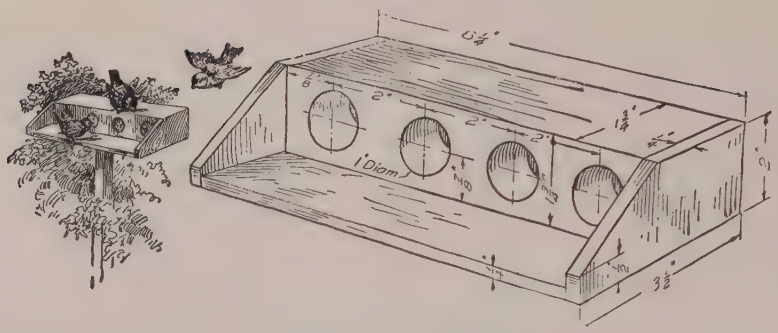


Fig. 490.—Prob. 200. Bird feeding stick.

Prob. 200. Fig. 490. Make a working drawing of the **bird feeding stick**.

Prob. 201. Fig. 491. Make a working drawing of the **martin house.** Consider the choice and treatment of views and choice of scale. Material is ⅜" white pine. Supply details and dimensions not shown in the pictures.

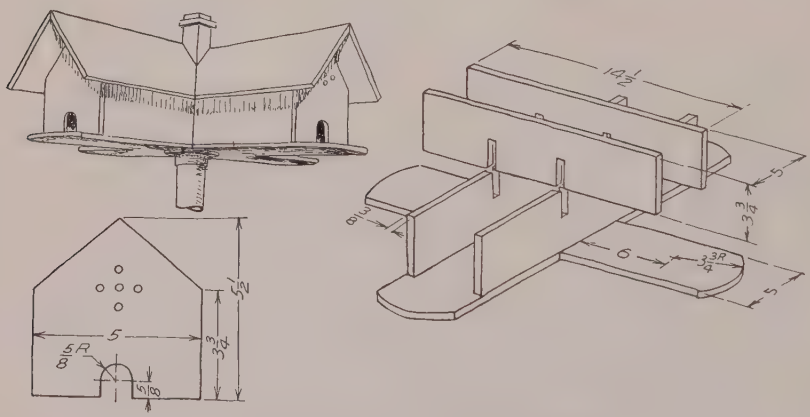


Fig. 491.—Prob. 201. Martin house.

Prob. 202. Fig. 492. Make a working drawing of the **radio shelf.** Select views and scale.

Prob. 203. Fig. 493. Make a working drawing of the **book rack.** Select views and scale.

Prob. 204. Fig. 494. Make a working drawing of the **four-compartment book rack.** Select views and scale.

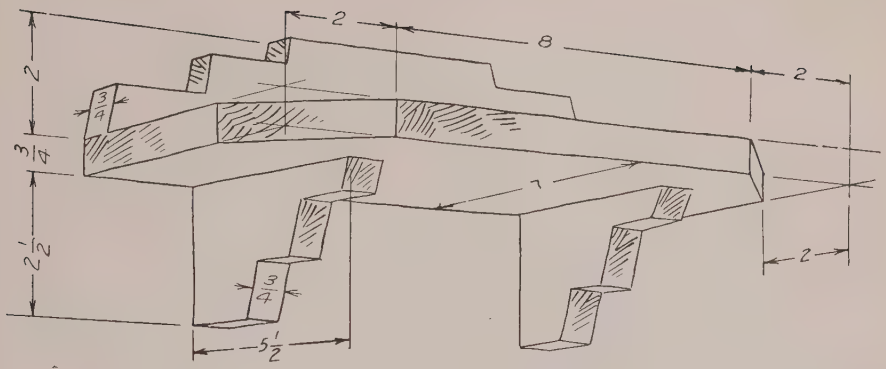


FIG. 492.—Prob. 202. Radio shelf.

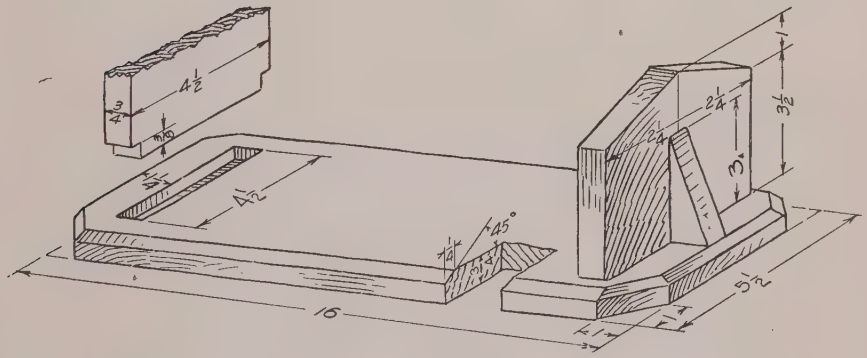


FIG. 493.—Prob. 203. Book rack.

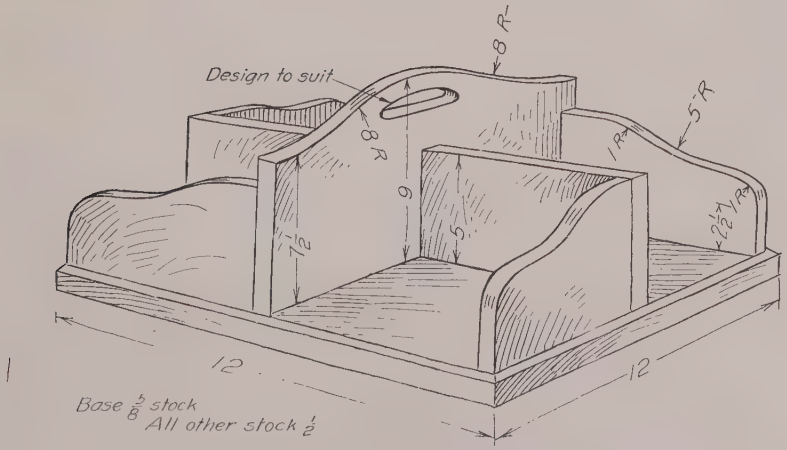


FIG. 494.—Prob. 204. Four-compartment book rack.

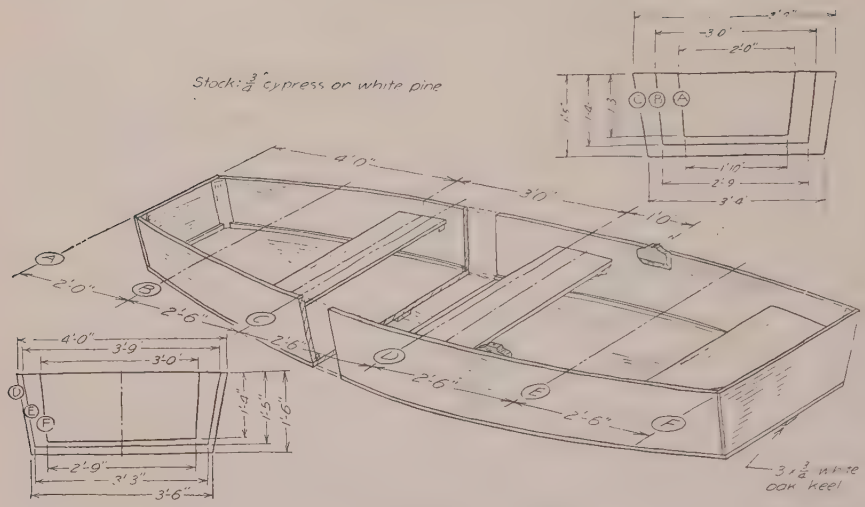


FIG. 495.—Prob. 205. Boat.

Prob. 205. Fig. 495. Make detail and assembly drawings for the **boat.** The shape is defined by the inside dimensions of the bulkheads *A*, *B*, *C*, *D*, *E* and *F*. These shapes may be drawn separate or "stacked." The widths of the seats from bow to stern are 1′-0″, 1′-3″ and 1′-3″. Select views and scale. Use two standard sheets.

Prob. 206. Fig. 496. Make an assembly working drawing, with extra part views if necessary, for the **tea table.** Supply missing dimensions.

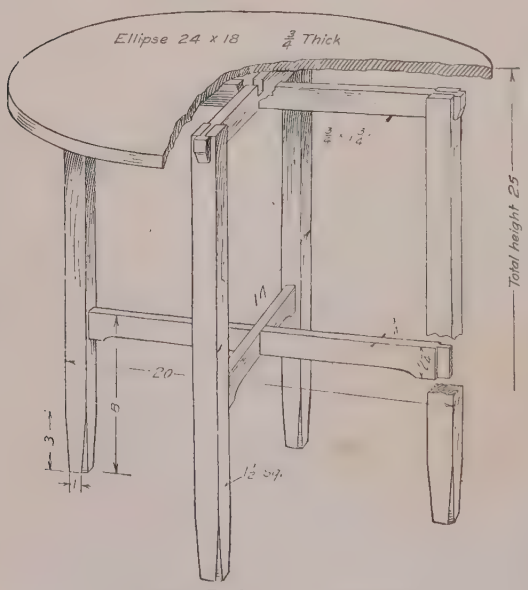


FIG. 496.—Prob. 206. Tea table.

Prob. 207. Fig. 497. Make an assembly working drawing, with extra part views if necessary, of the **costumer.**

Prob. 208. Fig. 498. Make an assembly working drawing of the **book pier.** Design the construction of the drawer.

Prob. 209. Fig. 499. Make an assembly working drawing of the **magazine table,** with necessary detail views.

Prob. 210. Fig. 500. Make a complete working drawing, assembly and details, for a **folding card table.**

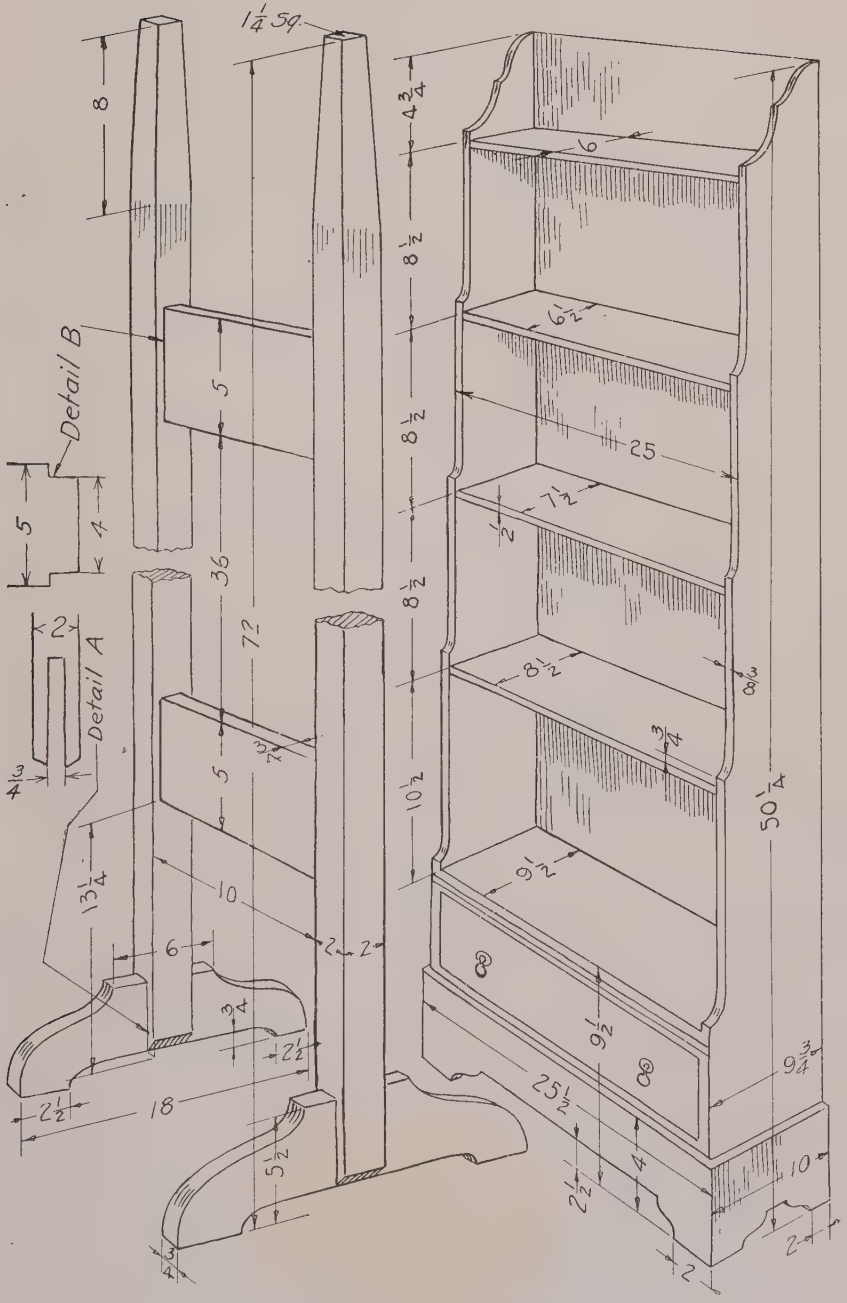


Fig. 497.—Prob. 207. Costumer.

Fig. 498.—Prob. 208. Book pier.

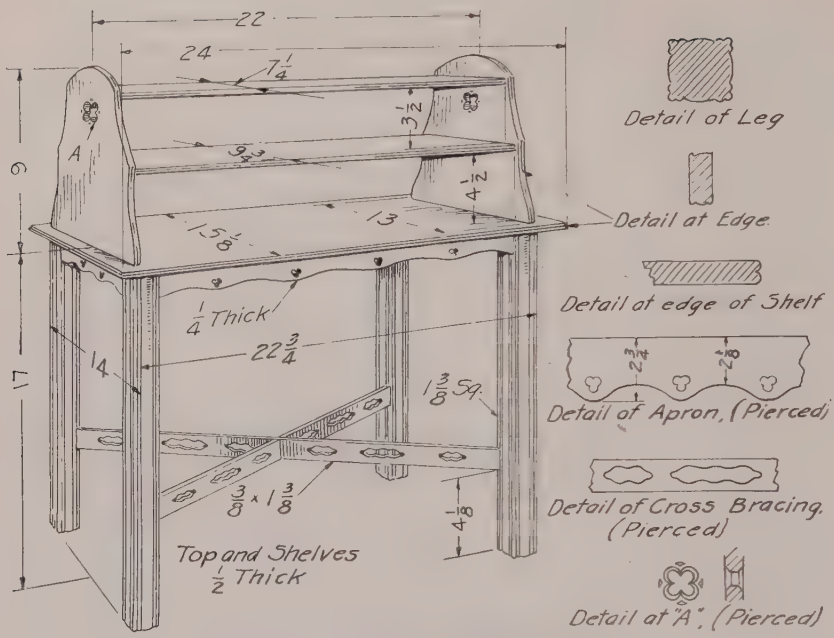


FIG. 499.—Prob. 209. Magazine table.

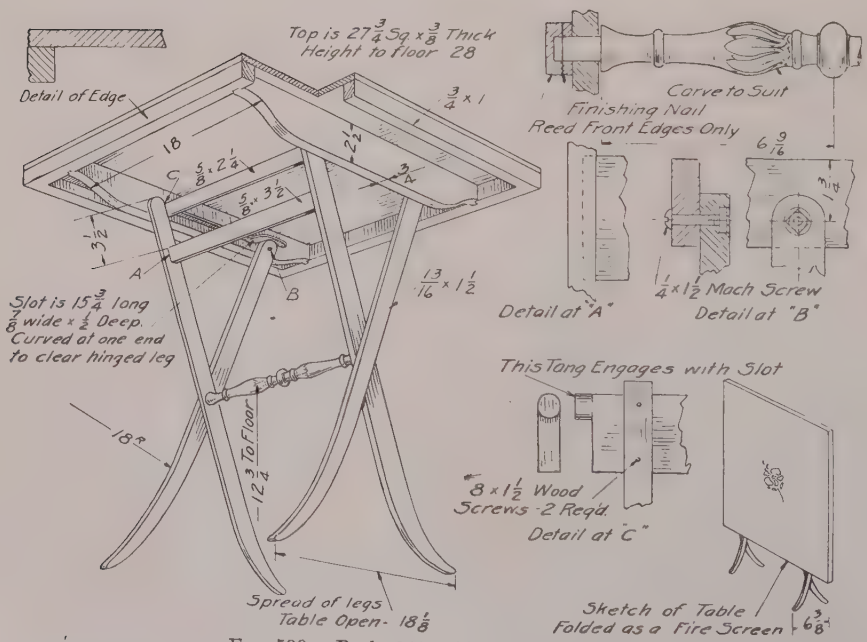


FIG. 500.—Prob. 210. Folding card table.

Group XII. Assembly and Detail Drawings.

Before starting these problems, study the views given and see just what is required in each case. See how many pieces are to be represented and the best method of showing them. It will be necessary to use judgment to arrange for the spacing of the views for detail drawings of several pieces. Each piece should be completely dimensioned and should be named.

Assembly drawings may have different treatments according to the purpose to be served. They may have no dimensions; they may have dimensions necessary for assembling or erection, for operation, etc.; or they may have all dimensions. If not stated in the problem, consult your instructor.

The chapters on size description, technic of the finished drawing, bolts and screws and mechanical drafting should be used for study and reference in connection with these assembly and detail drawings.

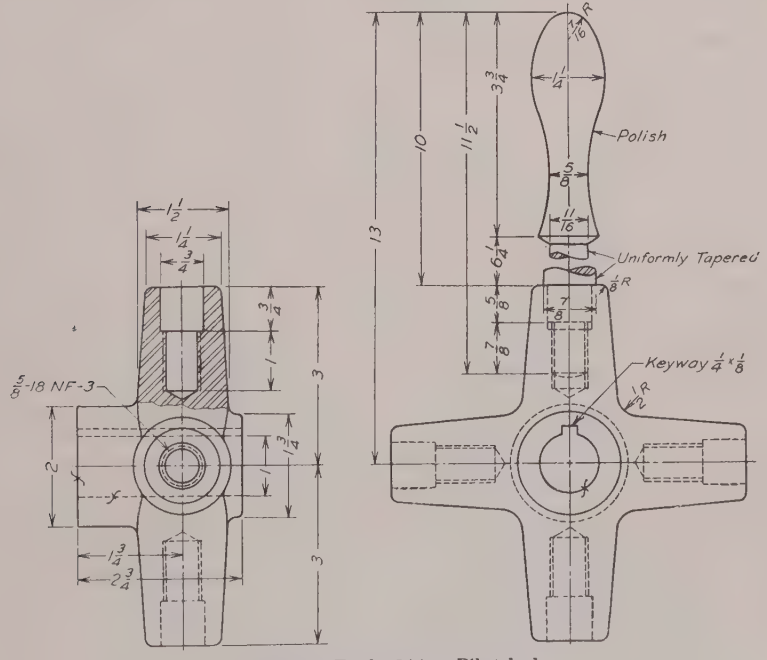


Fig. 501.—Prob. 211. Pilot hub.

Prob. 211. Fig. 501. Make detail drawings of the **pilot hub,** showing each piece fully dimensioned.

Prob. 212. Fig. 502. Make detail drawings of the **pivot-guide roll.**

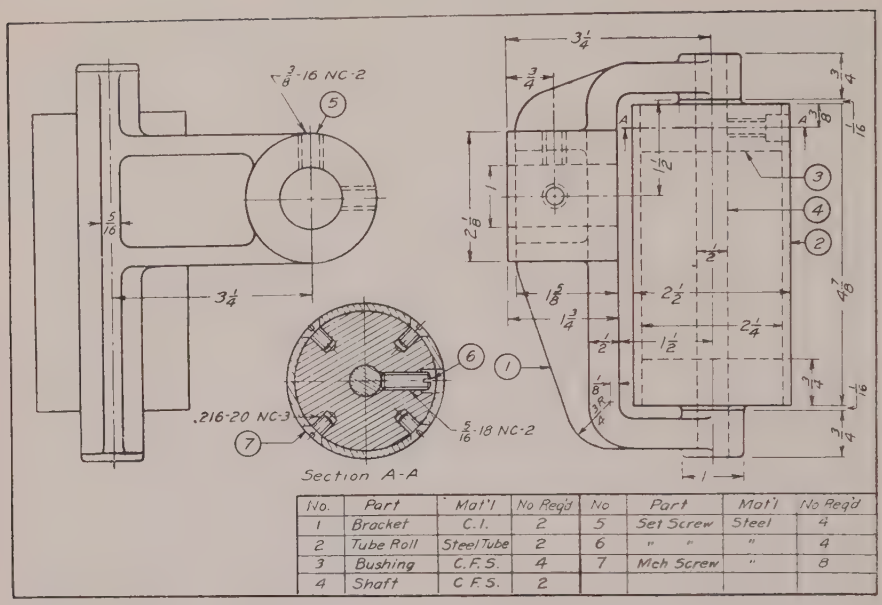
Prob. 213. Fig. 503. Make detail drawings of the **bell-crank reverse.**

Prob. 214. Fig. 504. Make detail drawings of the **crane hook.**

Prob. 215. Fig. 505. Make detail drawings of the **roller bracket.**

Prob. 216. Fig. 506. From the details make a two-view assembly drawing of the **tool post.** Dimension as required by your instructor.

Prob. 217. Fig. 507. Make an assembly drawing of the **idler pulley,** two views, full size, showing pulley, bushing and upper end of frame in section.



No.	Part	Mat'l	No Req'd	No	Part	Mat'l	No Req'd
1	Bracket	C.I.	2	5	Set Screw	Steel	4
2	Tube Roll	Steel Tube	2	6	" "	"	4
3	Bushing	C.F.S.	4	7	Mch Screw	"	8
4	Shaft	C.F.S.	2				

FIG. 502.—Prob. 212. Pivot-guide roll.

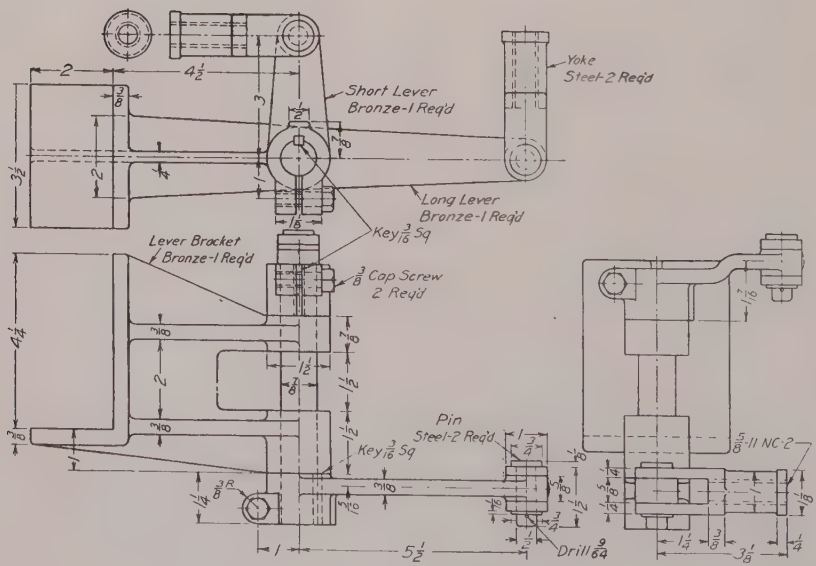


FIG. 503.—Prob. 213. Bell-crank reverse.

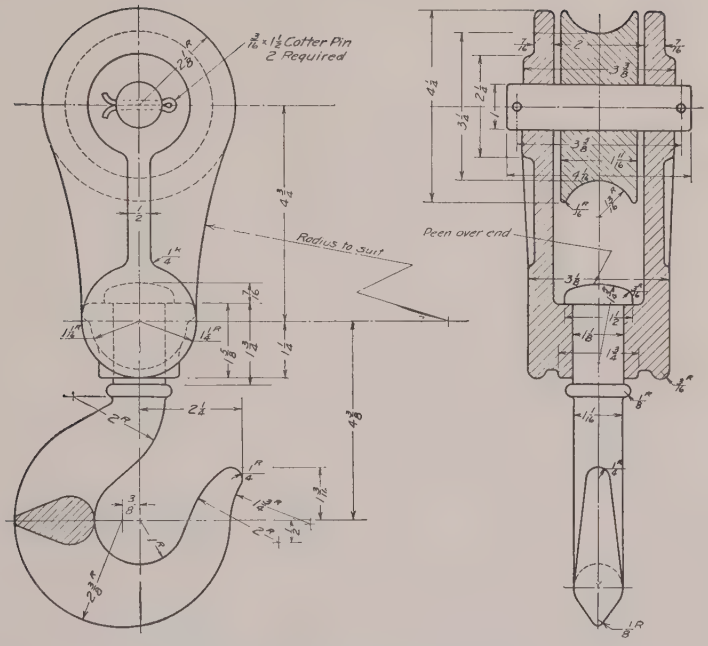


FIG. 504.—Prob. 214. Crane hook.

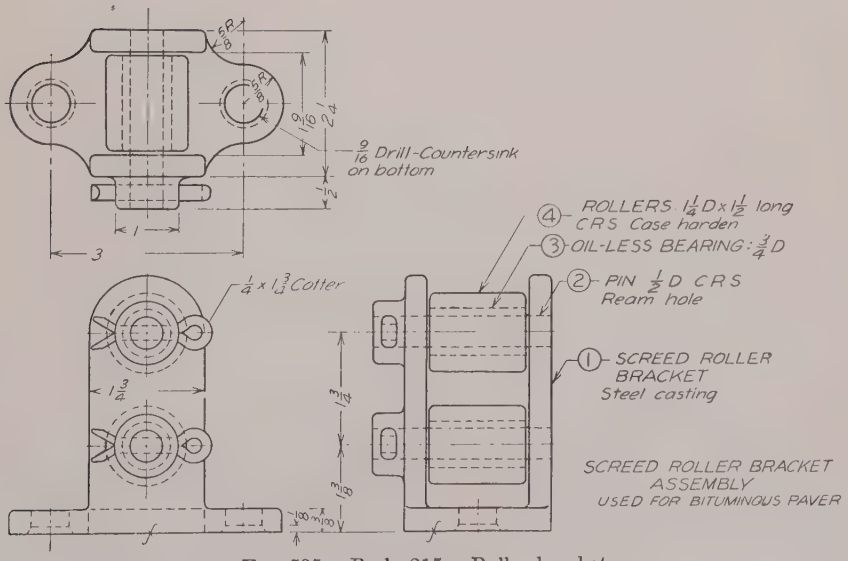
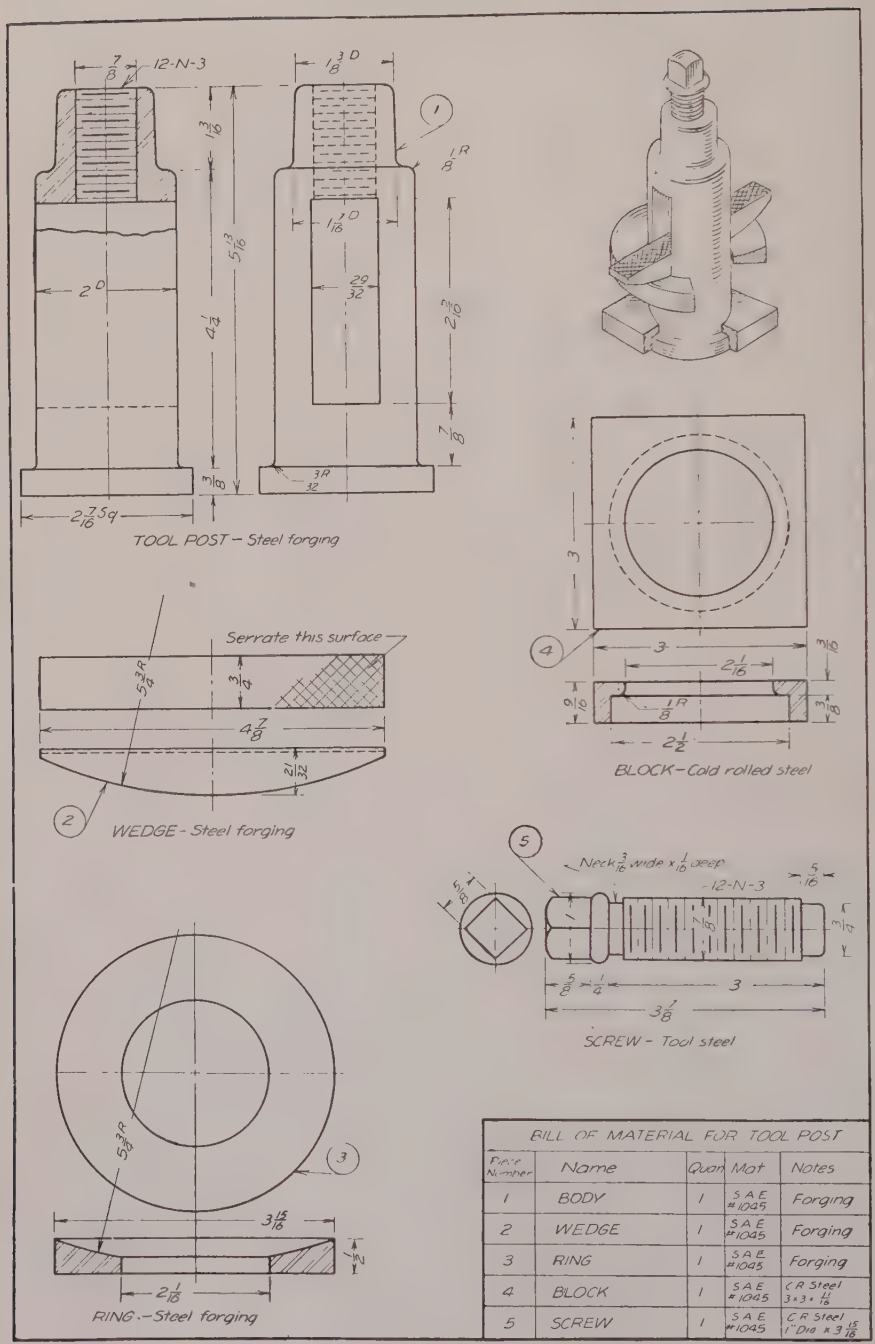


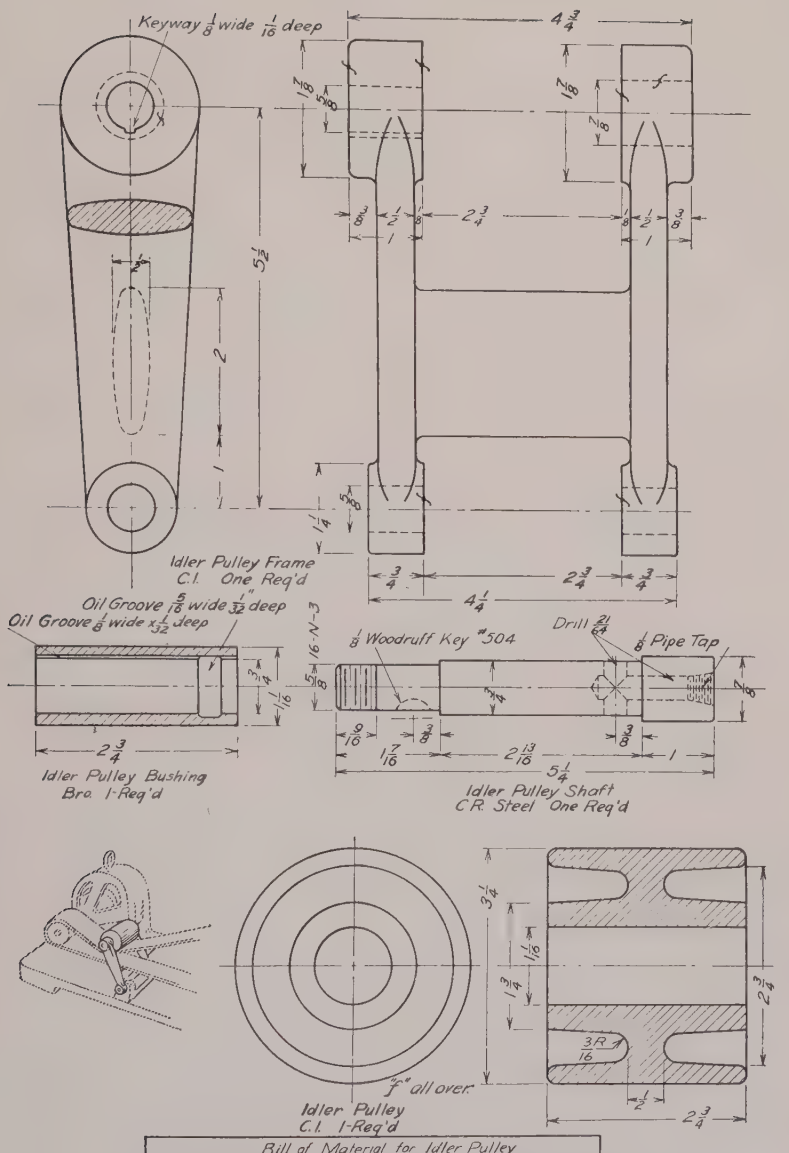
FIG. 505.—Prob. 215. Roller bracket.



BILL OF MATERIAL FOR TOOL POST

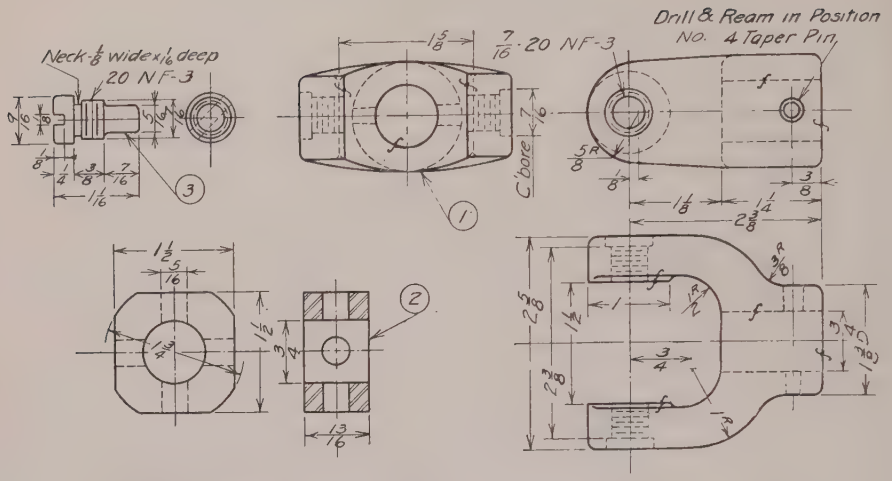
Piece Number	Name	Quan	Mat	Notes
1	BODY	1	SAE #1045	Forging
2	WEDGE	1	SAE #1045	Forging
3	RING	1	SAE #1045	Forging
4	BLOCK	1	SAE #1045	CR Steel 3 x 3 x 11/16
5	SCREW	1	SAE #1045	CR Steel 1" Dia x 3 15/16

FIG. 506.—Prob. 216. Tool post.



Bill of Material for Idler Pulley			
Name	Quan	Mat.	Notes
Idler Pulley	1	C.I.	
Idler Pulley Frame	1	C.I.	
Idler Pulley Bushing	1	Bro.	
Idler Pulley Shaft	1	C.R.S.	
5/8 S.A.E. Hex Nut	1		3/8 High Purchased
1/8 Woodruff Key #504	1		Purchased
1/8 Std. Alemite Oiler	1		Purchased

FIG. 507.—Prob. 217. Idler pulley.



Bill of Material for Universal Joint				
No.	Name	Quan	Mat	Notes
1	Fork	2	CI	
2	Ring	1	Steel	
3	Stud	4	Steel	
	No. 4 Taper Pin	2		Purchased

FIG. 508.—Prob. 218. Universal joint.

Prob. 218. Fig. 508. Make a two-view assembly drawing of the **universal joint,** in section.

Prob. 219. Fig. 509. Make working detail drawings of clutches, driving and driven; clutch cross, muff coupling, collar, bushing and key, with bill of material for complete unit of the **Oldham coupling** (used for connecting the ends of two rotating shafts, not in accurate alignment). Full size. Two sheets.

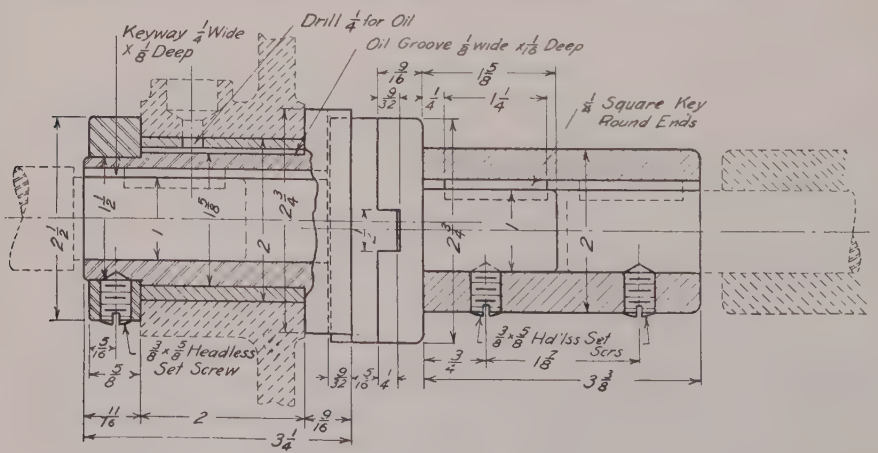
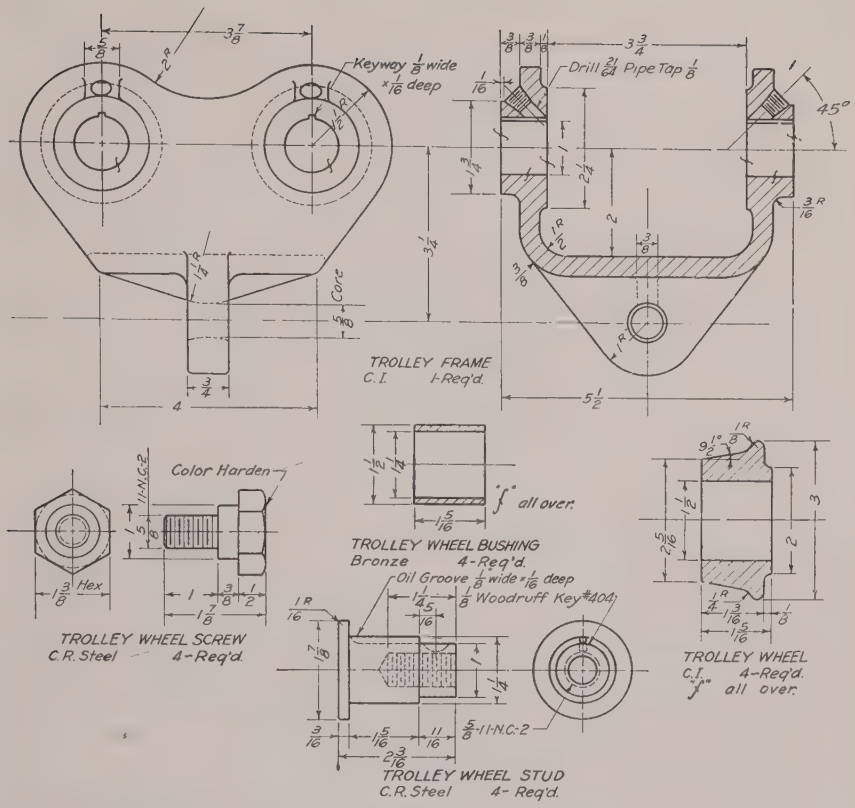


FIG. 509.—Prob. 219. Oldham coupling.



BILL OF MATERIAL FOR JIB CRANE TROLLEY			
NAME	QUAN.	MAT'L.	NOTES
Trolley Frame	1	C.I.	
Trolley Wheel	4	C.I.	
Trolley Wheel Bushing	4	Bro.	
Trolley Wheel Stud	4	C.R.S.	
Trolley Wheel Screw	4	C.R.S.	
1/8 Woodruff Key #404	4		Purchased
1/8 Std. Alemite Oiler	4		Purchased
1 Lock Washer	4		Purchased

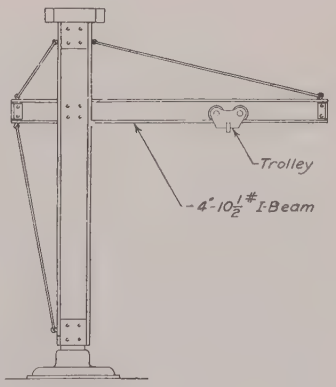


FIG. 510.—Prob. 220. Jib crane trolley.

Prob. 220. Fig. 510. Make an assembly drawing of the **jib crane trolley,** two views, full size. Draw side view in section as shown in detail of frame. The I beam may be indicated in dotted section on this view if desired, obtaining dimensions from a structural-steel handbook.

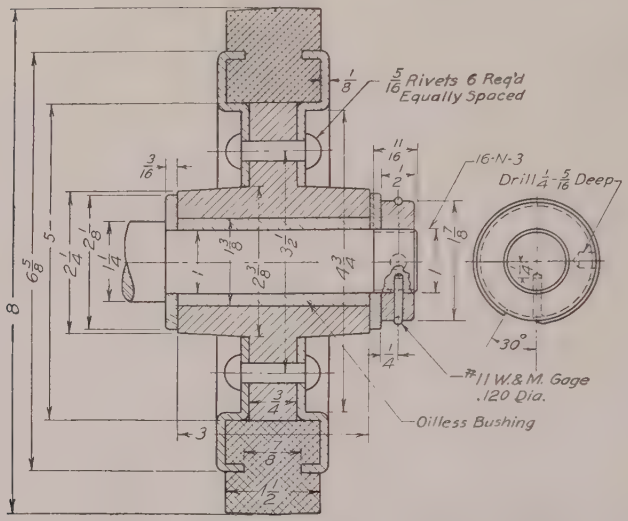


FIG. 511.—Probs. 221 and 222. Cushion wheel.

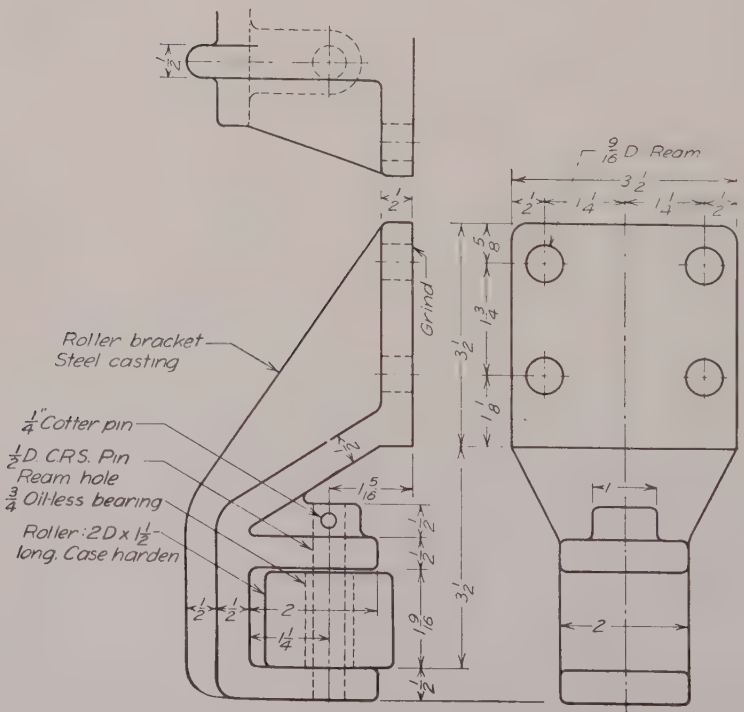

9/16 D Ream
Grind
Roller bracket Steel casting
1/4" Cotter pin
1/2 D. CR.S. Pin Ream hole
3/4 Oil-less bearing
Roller: 2D x 1 1/2 long. Case harden

FIG. 512.—Probs. 223 and 224. Hanger bracket.

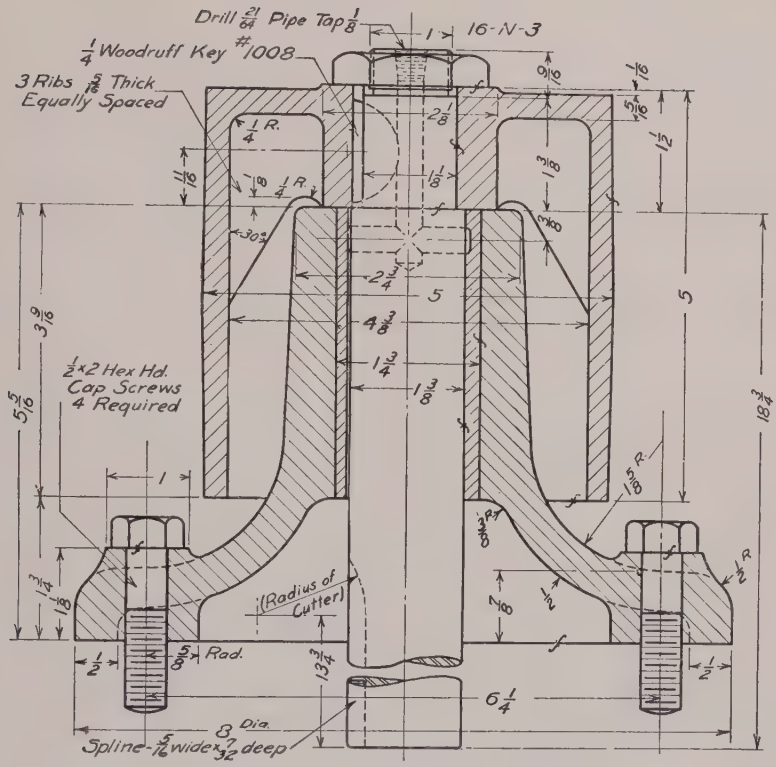


FIG. 513.—Prob. 225. Pulley and stand.

Prob. 221. Fig. 511. Make a front view and section of **cushion wheel,** full size. This type of wheel is used on warehouse or platform trucks to reduce noise and vibration.

Prob. 222. Fig. 511. Make a complete set of detail drawings, full size, with bill of material, for the **cushion wheel.** Three sheets will be needed. Rivets are purchased and therefore would not be detailed but would be specified in the bill of material.

Prob. 223. Fig. 512. Make a complete assembly drawing of the **hanger bracket.** Place the vertical distances of the figure parallel to the long dimension of the sheet. Supply the missing details.

Prob. 224. Fig. 512. Make a complete set of detail drawings with bill of material for the **hanger bracket.**

Prob. 225. Fig. 513. Make working detail drawings of base, pulley, bushing and shaft, with bill of material for complete **pulley and stand** unit. Full size, three sheets. If necessary, the top view of base may be a "half plan."

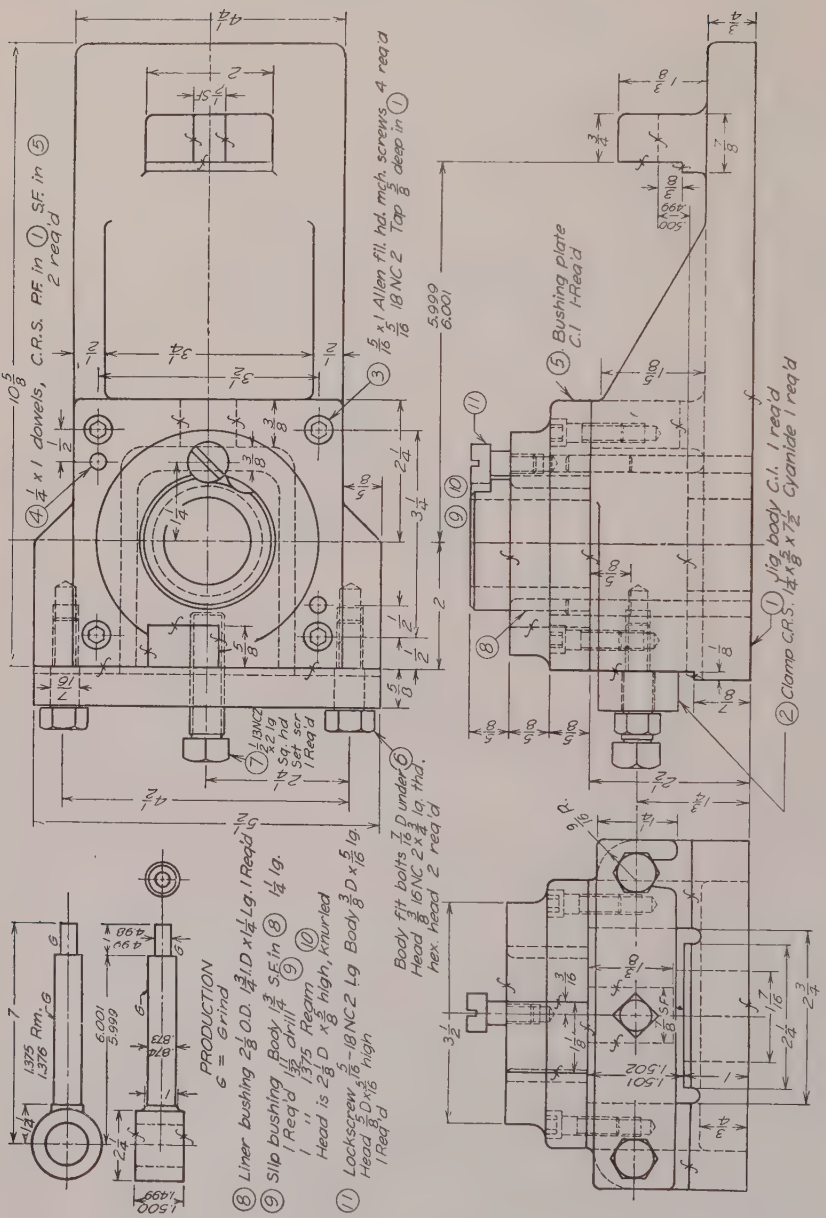

PRODUCTION
G = Grind
⑧ Liner bushing 2 1/8 O.D. 1 3/4 I.D x 1 1/4 Lg. 1 Req'd
⑨ Slip bushing Body 1 3/4 S.F. in ⑧ 1 1/4 lg.
1 Req'd 1 1/2 drill ⑨ ⑩
1 " 1375 Ream
Head is 2 1/8 D x 5/8 high, Knurled
⑪ Lockscrew 5/16-18 NC 2 Lg Body 3/8 D x 5/8 lg.
Head 5/8 D x 5/16 high
1 Req'd
Body fit bolts 7/16 D under
Head 3/8-16 NC 2 x 3/4 lg. thd.
hex head 2 req'd
⑦ 1/2-13 NC 2 Lg
Soft rod
1 Req'd
④ 1/4 x 1 dowels, C.R.S. PF in ① SF in ⑤
2 req'd
③ 5/16 x 1 Allen fil. hd. mch. screws, 4 req'd
5/16-18 NC 2 Tap 5/8 deep in ①
⑤ Bushing plate
C.I. 1 Req'd
① Jig body C.I. 1 req'd
② Clamp C.R.S. 1 1/4 x 5/8 x 2 1/2 cyanide 1 req'd

Fig. 514.—Probs. 226, 227, 228. Jig.

Probs. 226, 227, 228. Fig. 514. A **jig** is a device used to hold a machine part (called the **work** or **production**) while it is being machined or "produced," so that all the parts will be alike within specified limits of accuracy. Note the **production** shown in the upper left-hand corner of the figure.

Prob. 226. Fig. 514. Make a detail working drawing of the **jig body.**

Prob. 227. Fig. 514. Make a complete set of detail drawings for the **jig,** with bill of material. Use as many sheets as necessary or larger sheets. The next larger American Standard size sheet is 17″ × 22″ outside or trim-line measurements.

Prob. 228. Fig. 514. Make a complete assembly drawing of the **jig,** three views. Give only such dimensions as are necessary for putting the parts together and using the jig.

Group XIII. Piping Drawings.

236. Information on sizes, dimensions, allowable pressures and materials, types and other necessary specifications for pipe, fittings and valves for a wide variety of uses is given in the published standards of the American Standards Association (A.S.A.), 29 W. 39th St., New York, from whom a complete list with prices may be obtained. Obtain dimensions of pipe fittings from the above standards or from a handbook or a piping catalogue. Study Arts. 126 to 129 before starting the following problems.

Prob. 229. Lay out a standard sheet (Fig. 336). Use the representations of Fig. 206. In the upper left-hand corner of the sheet draw a ½″ cross, full size. Plug the upper and left-hand outlets with square head and countersunk plugs, respectively. In the right outlet place a 4″ nipple, followed in order by the following fittings: standard ½″ screw union, ½″ nipple, ½″ street ell, ½″ to ⅜″ reducing coupling, ⅜″ nipple, ⅜″ 45° branch, ⅜″ nipple in angle outlet of branch, 45° ell, ⅜″ pipe, ½″ to ⅜″ reducing bushing, ½″ standard ell and ½″ nipple. This last nipple should screw into the lower outlet of the cross, thus closing the system. The run outlet of the branch should be plugged.

Prob. 230. In the upper left-hand corner of the sheet draw, full size, a ½″ standard tee with the run outlets horizontal. Place a countersunk plug in the left-hand outlet. Starting at the right-hand outlet, draw the following fittings in the order mentioned below, the last nipple fitting in the bottom outlet of the tee. Nipple, globe valve, nipple, ell, nipple, 45°—½″ × ½″ × ⅜″ branch, ⅜″ nipple, 45° ell, nipple, R & L coupling, nipple, ½″ to ⅜″ reducing bushing, ½″ screwed union, street ell, nipple, coupling and nipple. Place a nipple and cap in the run outlet of the branch. Use the representations of Fig. 206.

Prob. 231. Draw two horizontal center lines 6¾″ apart and between them a third 3″ from the lower one. Draw two vertical center lines 10″ apart. On these center lines draw the following pipe fittings, full size, making two closed systems interconnected. ½″ standard tee, square-head plug, ½″ to ⅜″ reducing coupling, ⅜″ standard coupling, ⅜″ R & L coupling, ⅜″ angle valve, ⅜″—45° branch, ½″ to ⅜″ reducing bushing, ½″ street ell, ½″ gate valve, ½″ screwed union, ½″ ell, ½″ × ½″ × ⅜″ tee, ⅜″ cross, ⅜″ countersunk plug, ⅜″ cap, ⅜″—45° ell. Use nipples to suit. Use the representations of Fig. 206.

Probs. 232, 233, 234. Same as Probs. 229, 230, 231, respectively, but use single-line conventions (see Fig. 211).

Group XIV. Gear and Cam Drawings.

Study Chap. XII carefully before starting the problems in this group. It will be necessary to make some calculations to obtain dimensions for the gear drawings. Formulas are given in Art. 132. The formulas used, the given values, the calculations and the figured values should be neatly lettered on the drawing or on a separate sheet as directed by your instructor.

Accuracy and neatness are necessary to obtain satisfactory cam drawings. The pencil must be kept very sharp and the lines made fine and light. When the cam outline has been accurately plotted, it should be brightened, using a sharp pencil with the irregular curve.

Prob. 235. Make a working drawing for a **cut spur gear** similar to Fig. 217, but with 72 teeth, 12 diametral pitch.

Prob. 236. Make a working drawing for a **cut spur gear.** Diametral pitch 6; pitch diameter 8″; width of face 1⅝″; diameter of shaft or bore 1⅞″; length of hub 2″.

Prob. 237. Make a working drawing for a **cut spur gear and a pinion.** Outside diameter of gear 6½″; width of face 1¼″; length of hub 1½″. Pitch diameter of pinion 1½″. Number of teeth 12 for pinion. Other dimensions to be worked up as views are drawn.

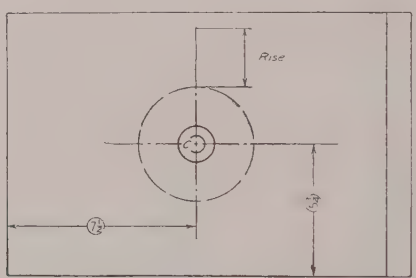


Fig. 515.—Probs. 238, 239, 240, 241.

Prob. 238. Fig. 515. Design a **plate cam** with point contact. See main drawing in Fig. 223. Motion of follower: rise 1½″ with uniform motion during one-half revolution, drop 1½″, at rest during remaining half revolution. Distance AC equals 2¼″.

Prob. 239. Fig. 515. Design a **plate cam** with point contact. Motion of follower: rise 2″ with uniform motion during one-third revolution, at rest during one-sixth revolution, drop 2″ uniformly during one-fourth revolution, at rest during remaining one-fourth revolution. Distance AC equals 1¾″.

Prob. 240. Fig. 515. Design a **plate cam with roller.** Motion of follower: rise 2″ with uniform motion during one-half revolution, drop 1″, remain at rest one-fourth revolution, drop 1″ with uniform motion during remaining one-fourth revolution. Diameter of roller ⅞″. Distance AC equals 2¼″.

Prob. 241. Fig. 515. Design a **plate cam with roller.** Motion of follower: rise 1¾″ with uniform motion during one-third revolution, drop ¾″, drop 1″ with uniform motion during one-third revolution, at rest during remaining one-third revolution. Diameter of roller ⅞″. Distance AC equals 2½″.

Group XV. Pictorial Drawing.

Study Chap. XIII carefully before commencing the problems.

The isometric cube with the two starting positions for the axes is shown in Figs. 226 and 227. Remember that all measurements must be taken parallel to the axes. In making oblique drawings note the two rules given in Art. 143.

Prob. 242. Fig. 516. Draw the two orthographic views. Construct the isometric drawing, using the axes in the second position, as indicated.

Prob. 243. Fig. 516. Draw the given orthographic views and an isometric drawing of the **notched block.**

Probs. 244 and 245. Figs. 517 and 518. Alternate problems for Prob. 242.

Probs. 246 and 247. Figs. 519 and 520. Alternate problems for Prob. 243.

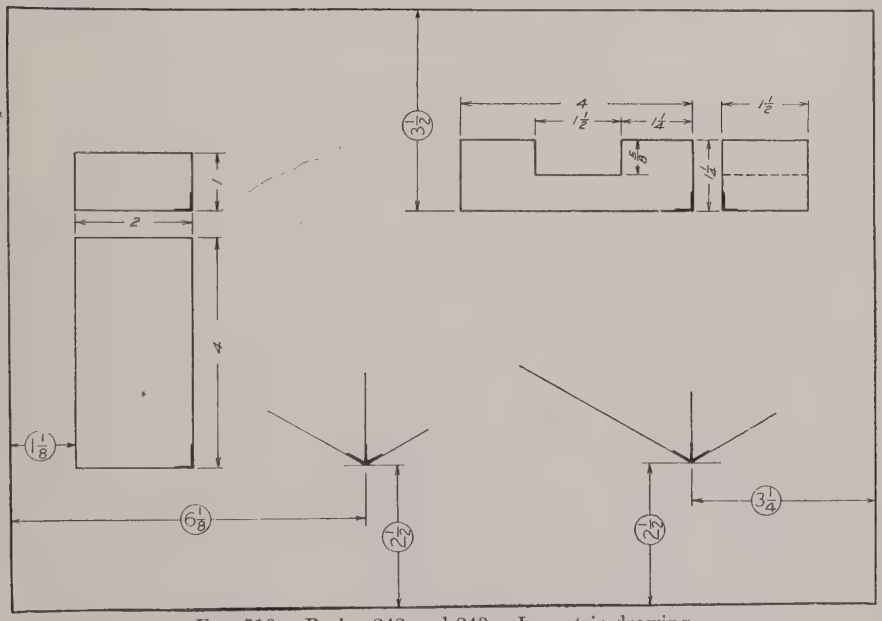


FIG. 516.—Probs. 242 and 243. Isometric drawing.

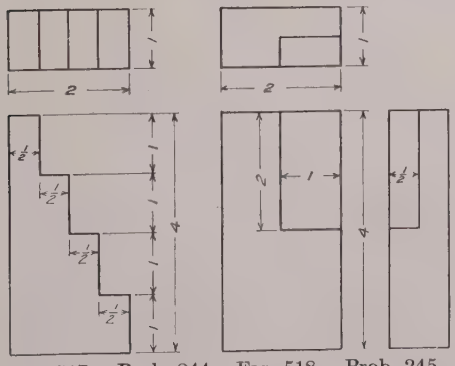


FIG. 517.—Prob. 244. FIG. 518.—Prob. 245.

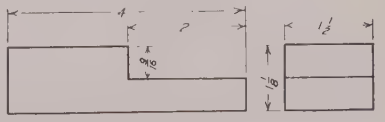


FIG. 519.—Prob. 246.

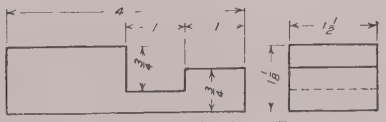


FIG. 520.—Prob. 247.

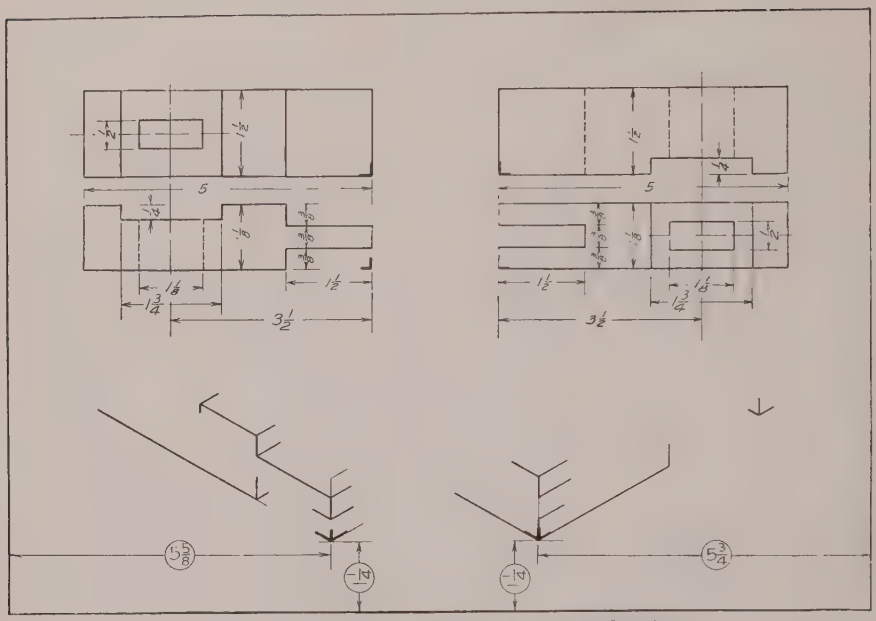


FIG. 521.—Probs. 248 and 249. Isometric drawing.

Prob. 248. Fig. 521. Draw the orthographic views given, and an isometric drawing of the **tenoned block.**

Prob. 249. Fig. 521. Draw the orthographic views given and an isometric drawing of the **mortised block.**

Prob. 250. Fig. 522. Alternate problem for Prob. 248.

Prob. 251. Fig. 523. Alternate problem for Prob. 249.

Prob. 252. Fig. 524. Alternate problem for Prob. 248.

Prob. 253. Fig. 525. Alternate problem for Prob. 249.

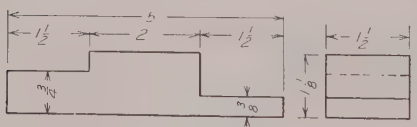


FIG. 522.—Prob. 250.

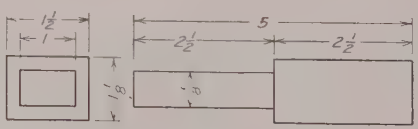


FIG. 523.—Prob. 251.

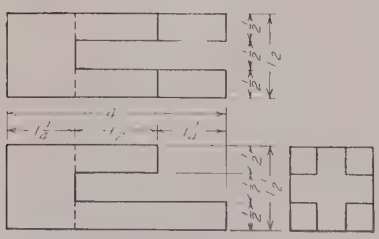


FIG. 524.—Prob. 252.

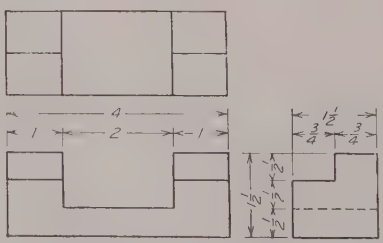


FIG. 525.—Prob. 253.

Prob. 254. Fig. 526. Draw the orthographic views given, and make an isometric drawing of the **wedge block** in the left-hand half of the sheet. This problem requires the locating of non-isometric lines. Read Art. 137, and observe the construction in Fig. 228 before starting this problem. The layout of Fig. 521 can be used. The construction lines should be drawn very light and either left on the drawing or not erased until they have been inspected by the instructor. The final lines of an isometric drawing should be brightened with a sharp pencil.

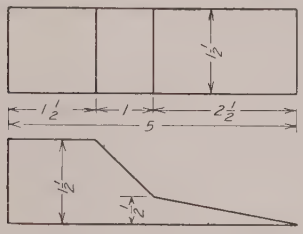


Fig. 526.—Prob. 254.

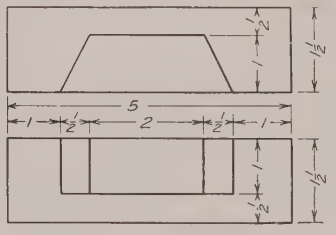


Fig. 527.—Prob. 255.

Prob. 255. Fig. 527. Draw the orthographic views given, and make an isometric drawing of the **recessed block** in the right-hand half of the sheet. This problem requires the locating of non-isometric lines. Read Art. 137 and observe the construction in Fig. 228 before starting this problem. The layout of Fig. 521 can be used. The construction lines should be drawn very light and either left on the drawing or not erased until they have been inspected by the instructor. The final lines of an isometric drawing should be brightened with a sharp pencil.

Prob. 256. Fig. 528. Draw the orthographic views given, and make an isometric drawing of the **double wedge** in the left-hand half of the sheet. This problem requires the locating of non-isometric lines. Read Art. 137 and observe the construction in Fig. 228 before starting this problem. The layout of Fig. 521 can be used. The construction lines should be drawn very light and either left on the drawing or not erased until they have been inspected by the instructor. The final lines of an isometric drawing should be brightened with a sharp pencil.

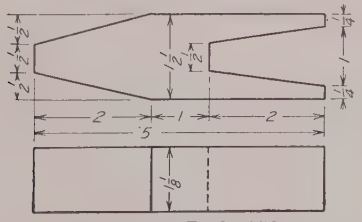


Fig. 528.—Prob. 256.

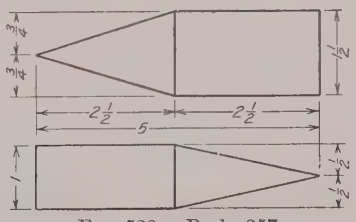


Fig. 529.—Prob. 257.

Prob. 257. Fig. 529. Draw the orthographic views given, and make an isometric drawing of the **double-end wedge** in the right-hand half of the sheet. This problem requires the locating of non-isometric lines. Read Art. 137 and observe the construction in Fig. 228 before starting this problem. The layout of Fig. 521 can be used. The construction lines should be drawn very light and either left on the drawing or not erased until they have been inspected by the instructor. The final lines of an isometric drawing should be brightened with a sharp pencil.

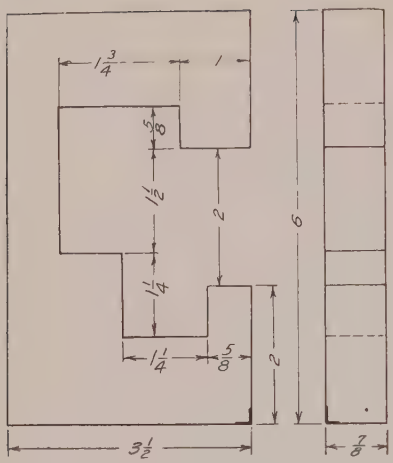


Fig. 530.—Prob. 258.

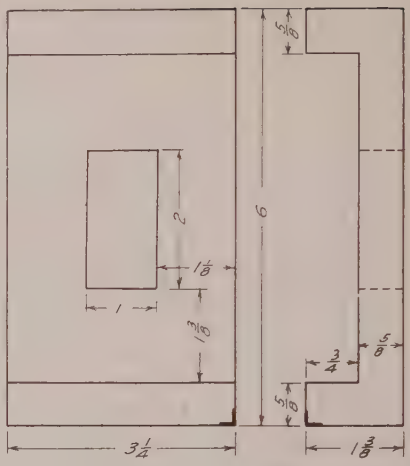


Fig. 531.—Prob. 259.

Prob. 258. Fig. 530. Make an isometric drawing of the **notched block.** Start with the corner indicated by heavy lines. Locate as in Fig. 532.

Prob. 259. Fig. 531. Make an isometric drawing of the **plate.** Locate as in Fig. 532.

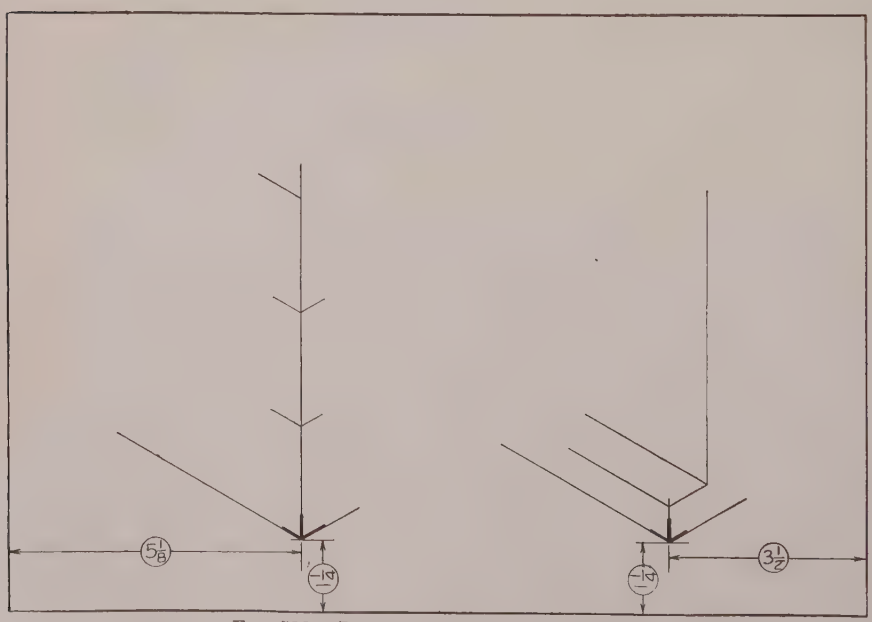


Fig. 532.—Layout for Probs. 258 and 259.

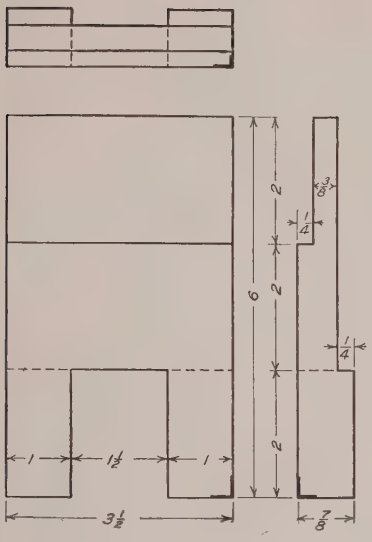


FIG. 533.—Prob. 260.

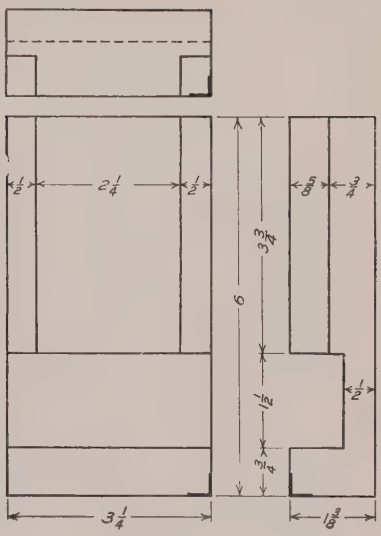


FIG. 534.—Prob. 261.

Prob. 260. Fig. 533. Make an isometric drawing of the **notched plate,** using layout of Fig. 532.

Prob. 261. Fig. 534. Make an isometric drawing of the **rabbeted stop,** using layout of Fig. 532.

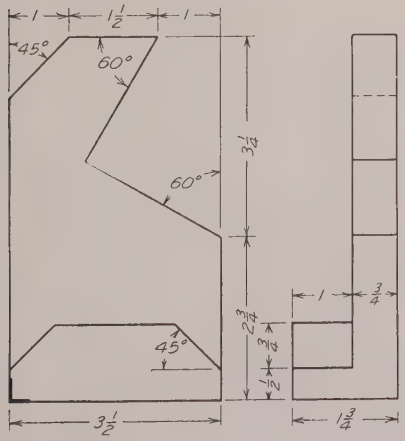


FIG. 535.—Prob. 262.

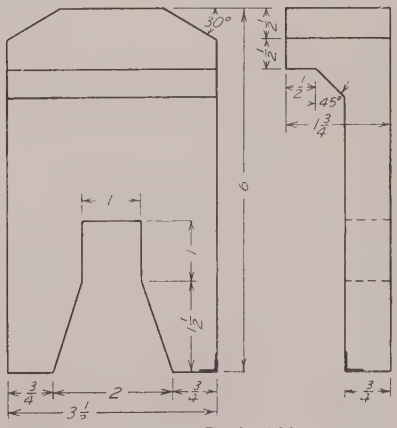


FIG. 536.—Prob. 263.

Prob. 262. Fig. 535. Make an isometric drawing of the **notched slide,** using layout of Fig. 532.

Prob. 263. Fig. 536. Make an isometric drawing of the **slotted stop,** using layout of Fig. 532.

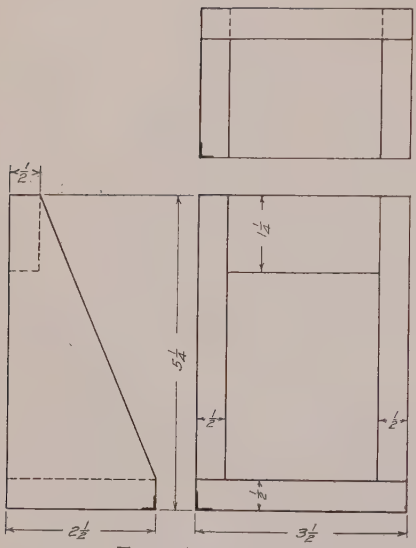


Fig. 537.—Prob. 264.

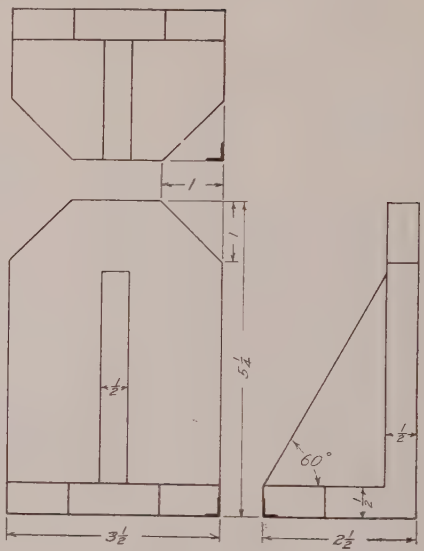


Fig. 538.—Prob. 265.

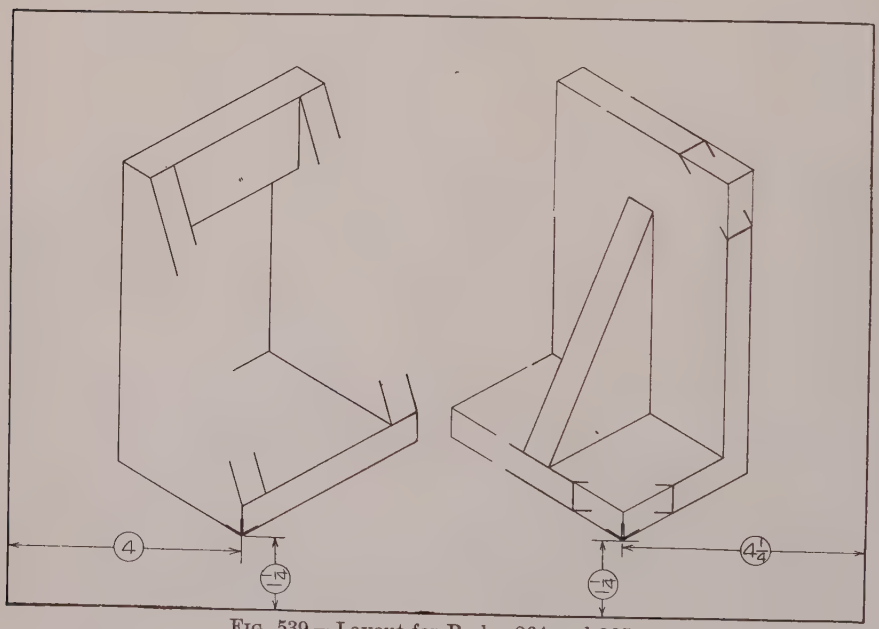


Fig. 539.—Layout for Probs. 264 and 265.

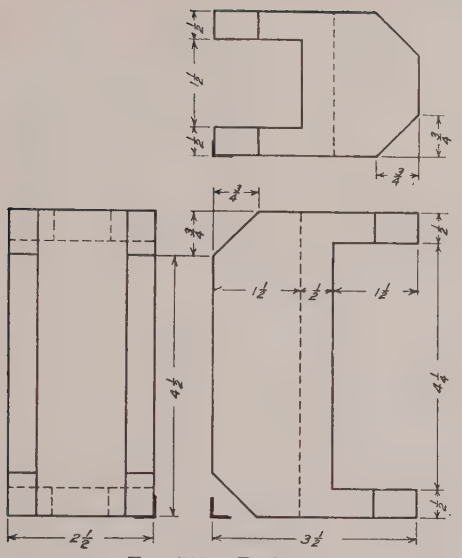


Fig. 540.—Prob. 266.

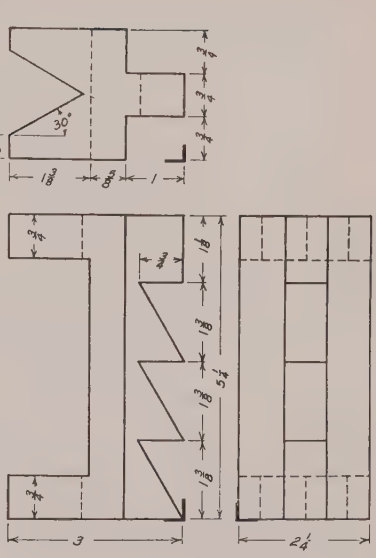


Fig. 541.—Prob. 267.

Prob. 264. Fig. 537. Make an isometric drawing of the **stirrup.** The drawing is started on the layout (Fig. 539). Note the heavy lines for the starting corner. The slant lines are non-isometric (Art. 137).

Prob. 265. Fig. 538. Make an isometric drawing of the **brace.** The drawing is started in Fig. 539. Note the 60° angle and read Art. 137 before asking for assistance in drawing it.

Prob. 266. Fig. 540. Make an isometric drawing of the **cross slide.** Read Arts. 107 and 108 before making the drawing. Locate as on Fig. 539. (An alternate for Prob. 263.)

Prob. 267. Fig. 541. Make an isometric drawing of the **adjustable ratchet.** Note the 30° angle and read Art. 137 before making the drawing. Locate as on Fig. 539. (An alternate for Prob. 264.)

Prob. 268. Fig. 542. Make an isometric drawing of a cube, each edge of which measures 3″. On each face construct an isometric circle by the method of Art. 138.

Prob. 269. Fig. 542. Make an isometric drawing of a cylinder 2½″ diameter and 3½″ high, resting on a square plate as shown. First draw the square plate. On it construct a square prism having sides of 2½″ and a height of 3½″. On the top and bottom faces of the prism construct isometric circles. Vertical tangent lines will complete the drawing. Note that the distance between these vertical lines is more than the actual diameter of the cylinder. Why?

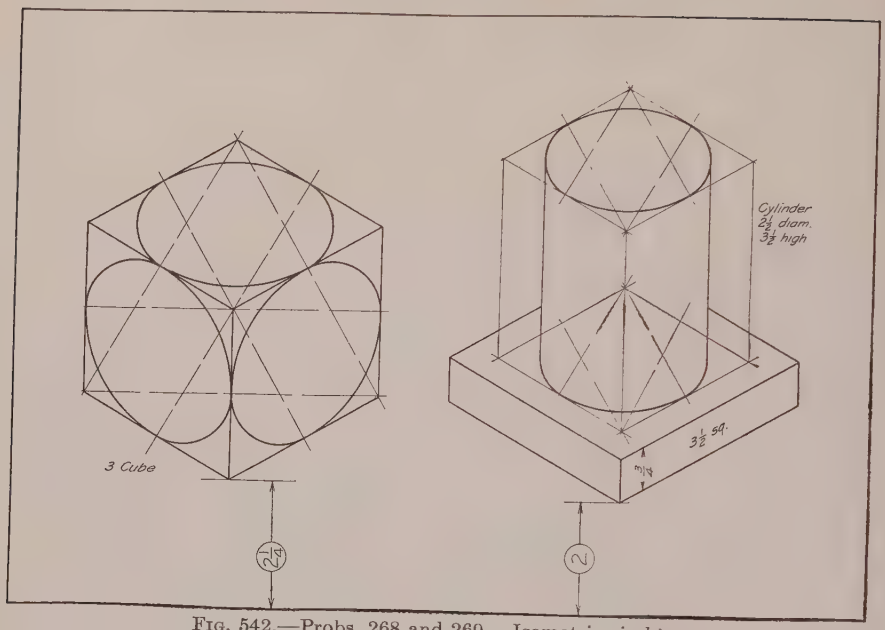


FIG. 542.—Probs. 268 and 269. Isometric circles.

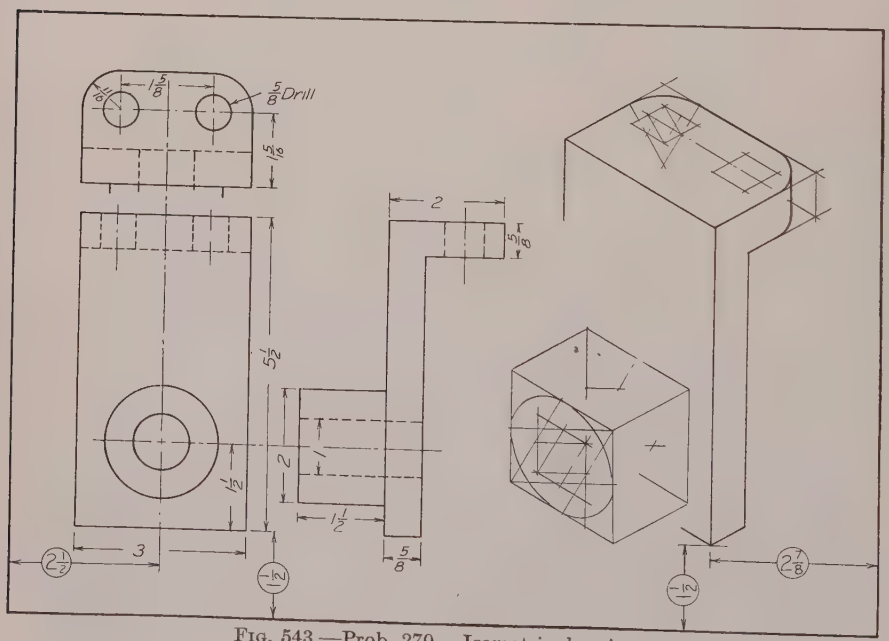


FIG. 543.—Prob. 270. Isometric drawing.

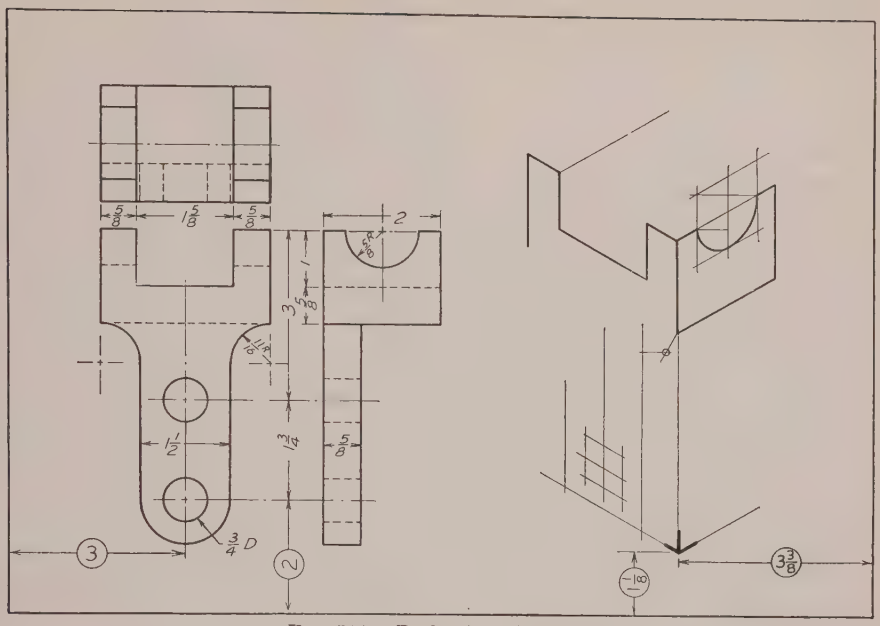


FIG. 544.—Prob. 271. Bracket.

Prob. 270. Fig. 543. Draw the three views given and an isometric drawing of the hung bearing. Most of the construction is indicated on the layout. Make the drawing as though all corners were square and then construct the curves as described in Art. 138.

Prob. 271. Fig. 544. Draw the three views given, then make an isometric drawing of the bracket. Some of the construction is indicated on the layout. Make the drawing as though the corners were square and then construct the curves. Read Art. 138. (An alternate for Prob. 270.)

Isometric Sections.—The next four problems are sectional views in isometric. As referred to in Art. 140, these are often useful in showing interior construction. The cutting planes must be isometric planes, that is, parallel to the faces of the isometric cube. Section lining is done with the 60° triangle. In making a full section, as for Probs. 272 and 274, draw the cut surface first, then add the part of the object behind it. For a half section, as called for in Probs. 273 and 275, it is usually best to draw the full isometric view, very lightly, first, then cut out the front quarter by two isometric planes, as indicated in the layouts (Figs. 547 and 550) and as shown in Figs. 232 and 233.

Prob. 272. Fig. 545. Make an isometric drawing in section, of the post socket. Locate as on Fig. 547.

Prob. 273. Fig. 546. Make an isometric drawing in half section, of the box step. Locate as on Fig. 547.

Prob. 274. Fig. 548. Make an isometric drawing of the post support. Locate as on Fig. 550.

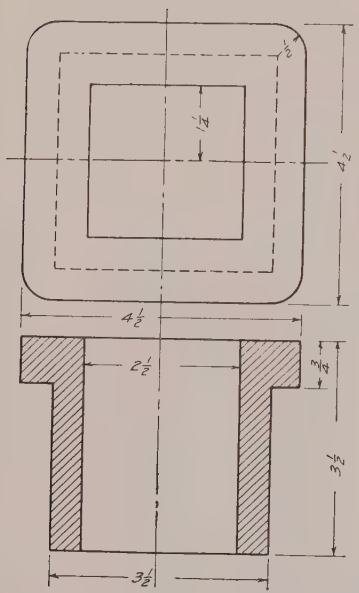


FIG. 545.—Prob. 272.

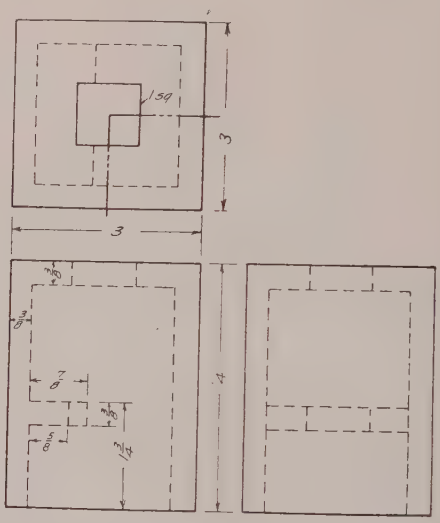


FIG. 546.—Prob. 273.

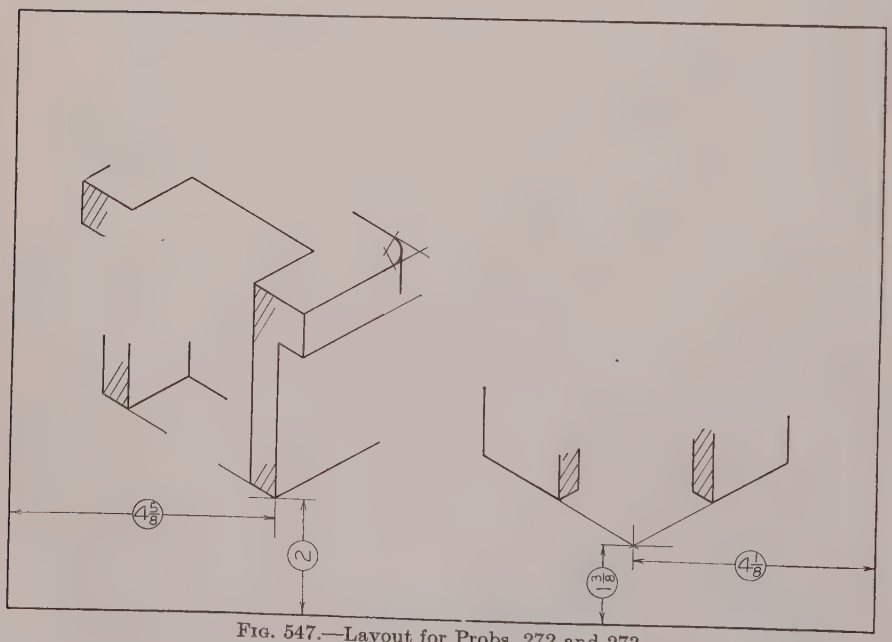


FIG. 547.—Layout for Probs. 272 and 273.

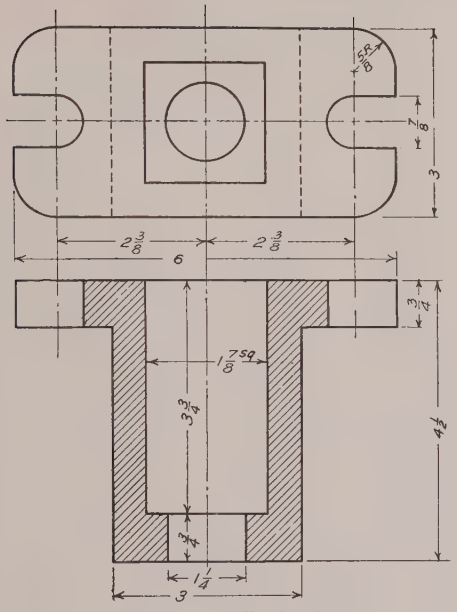


FIG. 548.—Prob. 274.

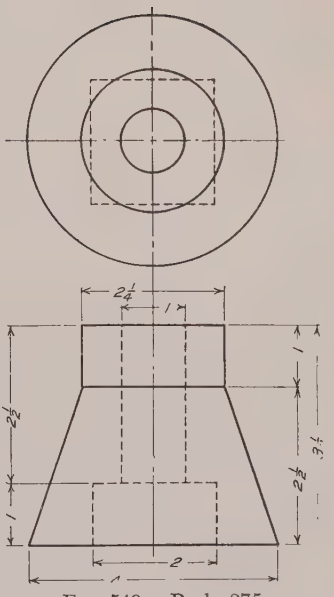


FIG. 549.—Prob. 275.

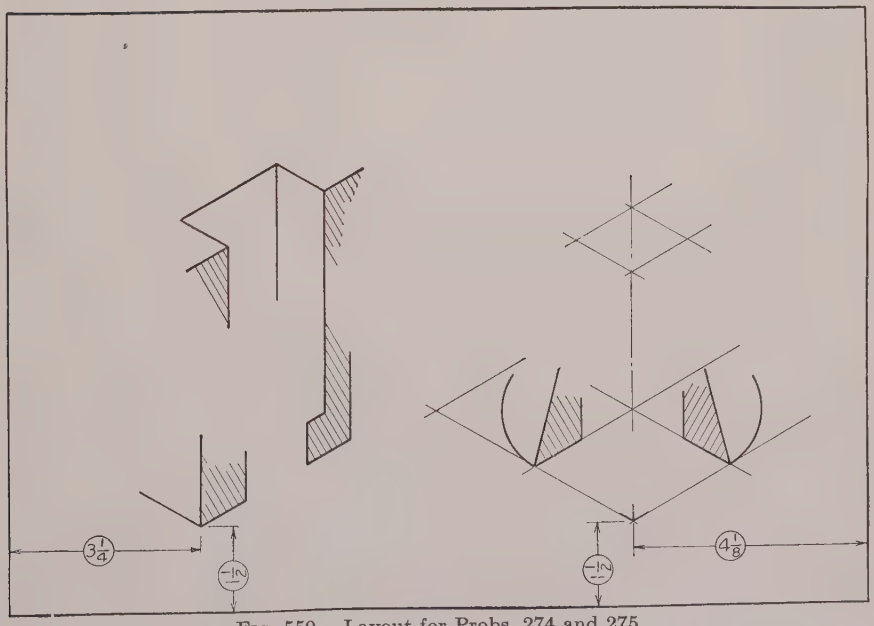


FIG. 550.—Layout for Probs. 274 and 275.

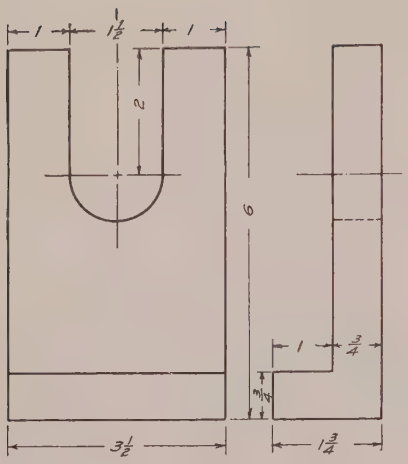


FIG. 551.—Prob. 276.

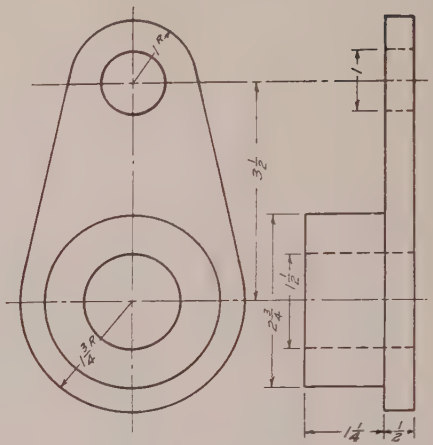


FIG. 552.—Prob. 277

Prob. 275. Fig. 549. Make an isometric drawing in half section, of the **foundation washer.** Locate as on Fig. 550.

Prob. 276. Fig. 551. Make an oblique drawing of the **angle piece,** using layout of Fig. 553. Read Arts. 143 to 145.

Prob. 277. Fig. 552. Make an oblique drawing of the **crank,** using position and layout of Fig. 553.

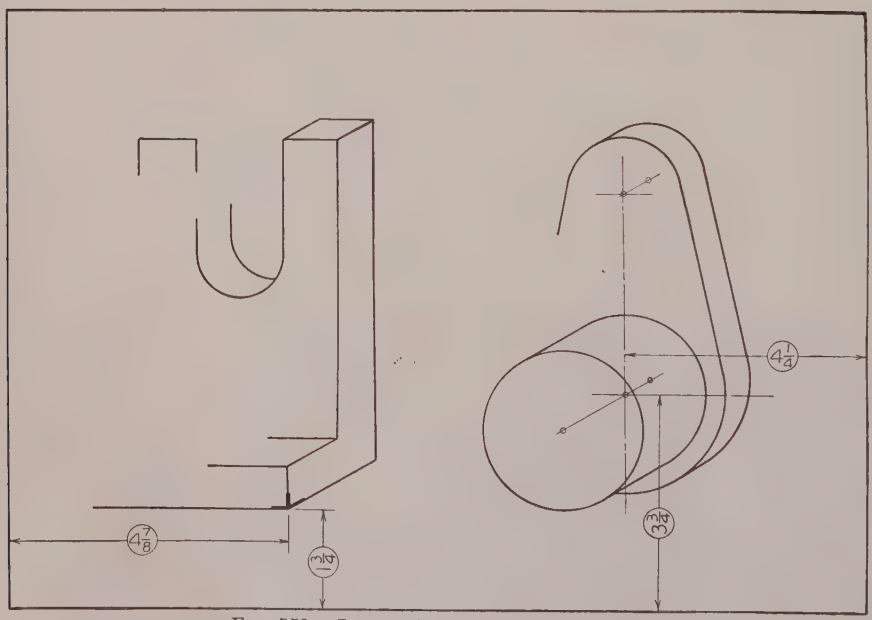


FIG. 553.—Layout for Probs. 276 and 277.

Prob. 278. Fig. 554. Make an oblique drawing of the **slotted sector.** This drawing can be made in one-half of a sheet (divided by a vertical line through the center). Use an axis of 30° or 45° to the right or left as directed by the instructor.

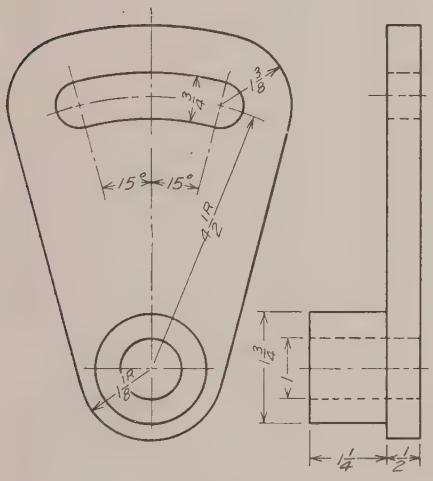


Fig. 554.—Prob. 278.

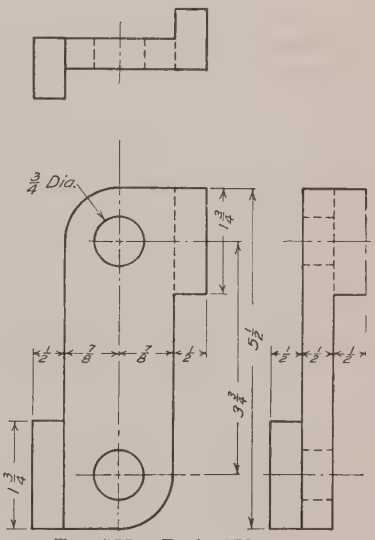


Fig. 555.—Prob. 279.

Prob. 279. Fig. 555. Make an oblique drawing of the **double stop.** This drawing can be made in one-half of a sheet (divided by a vertical line through the center). Use an axis of 30° or 45° to the right or left as directed by the instructor.

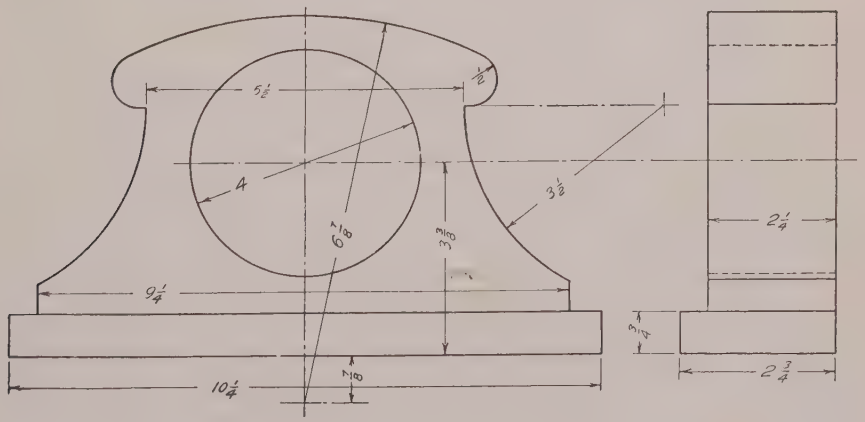


Fig. 556.—Prob. 280. Clock case.

Prob. 280. Fig. 556. Make an oblique drawing of the **clock case.** Use an axis of 30° to the right.

237. Pictorial Sketching.—One of the important uses of pictorial representation is in its application to the study of reading drawings and blue prints by means of freehand sketching. The following 24 problems are designed to test the ability to visualize shapes from orthographic views, as well as to give practice in the choice of methods of pictorial representation. They may be used to advantage as blackboard assignments, as freehand recitations on sketch paper or as finished sketches in the drawing room, placing four on a regular sheet.

Probs. 281 to 304. Figs. 559 to 561. Make freehand pictorial sketches of the objects shown, in any of the methods studied. Problem 281 is illustrated in Fig. 557 as it would appear when sketched in isometric and oblique drawing. The same problem is shown in Fig. 558 as a single figure on one sheet sketched in angular perspective. This sheet illustrates in general such assignments as may be made in pictorial sketching from actual parts of machines or other objects.

As described in Arts. 147 and 148 a perspective sketch is drawn from the object by estimating the directions of lines and proportions of lengths by observation, testing with the pencil as the sketch proceeds.

To make a sketch or drawing in angular perspective when the orthographic views are given instead of the object itself, the method generally used is what is known as the "cone of rays" method. In this method the plan is first drawn with its front corner against a line representing the picture plane, as shown in Fig. 558. Think of this as the top view of the object, with the picture plane standing up against the front edge. Imagine the observer standing out in front of the plane at the point S, looking at the object through the plane. There will be a ray of light from each point of the object to the observer's eye, and the picture as seen from this point will be the intersection of all these rays with the picture plane VV'. (To avoid distortion the station point S is taken at a distance from the picture plane at least twice the width or height of the object.) Thus if lines are drawn from the point S to the different points on the plan, their intersections with VV' will give the widths of the picture. Remember that so far we are looking down on the edge of the picture plane and the picture is all in the line VV'. A horizontal line on the picture plane at a height above the ground equal to the height of the observer's eye will be the horizon. From S lines drawn parallel to the lines of the plan will pierce the picture plane on the horizon, giving the vanishing points V and V'. Now imagine the picture plane to be detached and moved forward, then laid down into the plane of the paper. In the figure this has been done for convenience so that the horizon of the picture plane coincides with the line VV', which means practically that the line GL, which is the bottom edge of the picture plane, was drawn as far below VV' as the height of the observer's eye. At the intersection of GL and a perpendicular from the front corner of the plan, draw a vertical line representing the front edge of the object, and lines to V and V' for the lower horizontal edges. Perpendiculars dropped from the intersection of the rays with the picture plane will give the length and width of the object. Vertical measurements must all be made on the vertical line in the picture plane and vanished back to meet the location of the point to be measured.

A study of Fig. 558 will show the method of finishing the sketch.

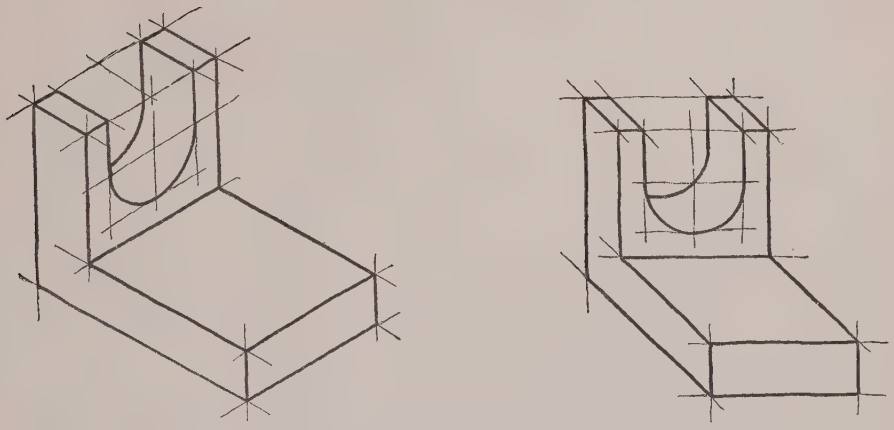


FIG. 557.—Solution of Prob. 281 in isometric and oblique.

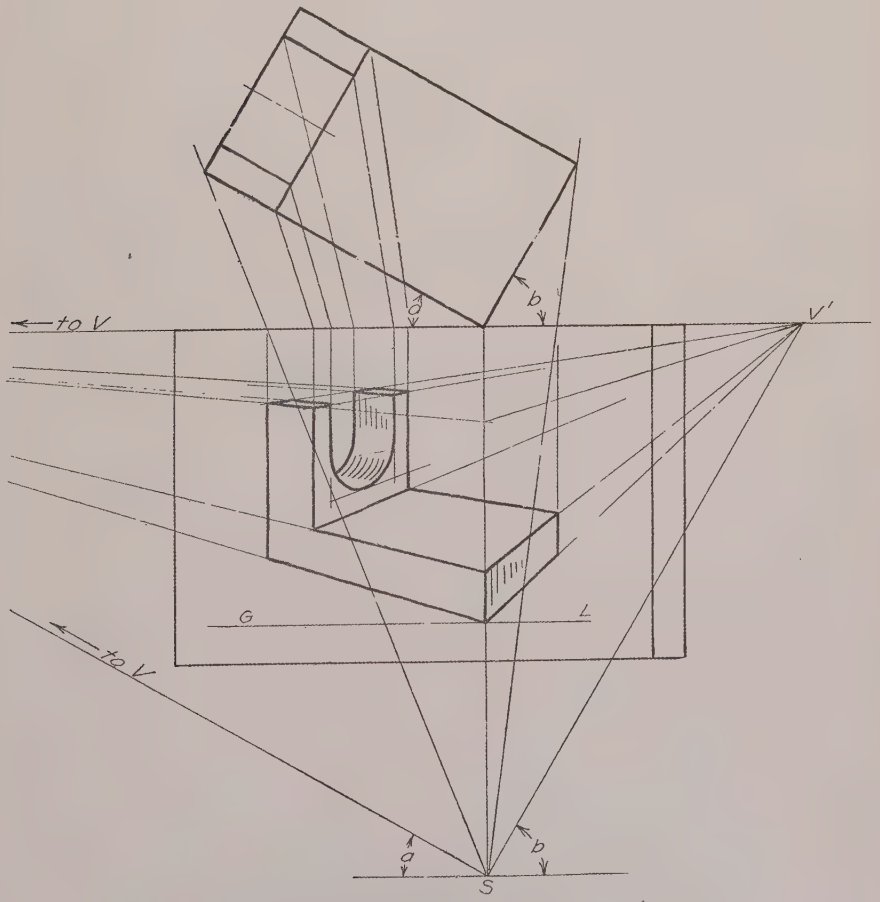
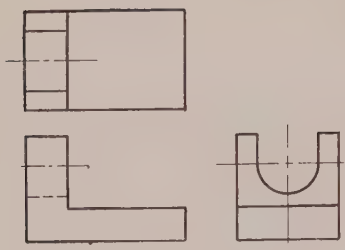
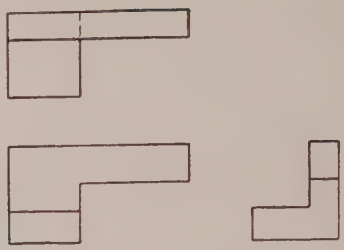


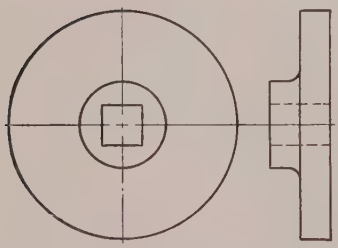
FIG. 558.—Solution of Prob. 281 in perspective.



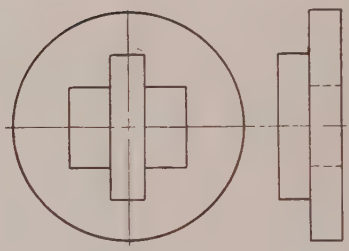
Yoke Bracket



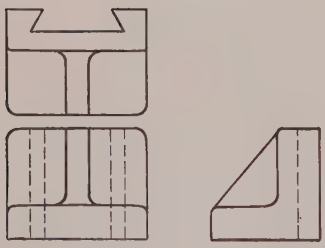
Blank for Tool Rest



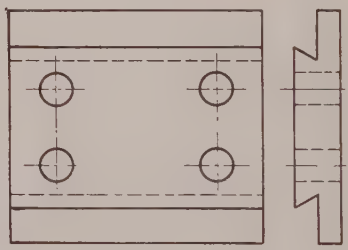
Gear Bracket



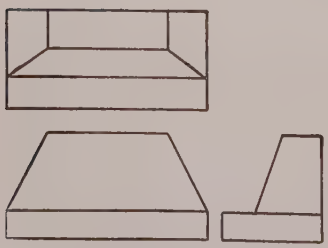
Disc Plate



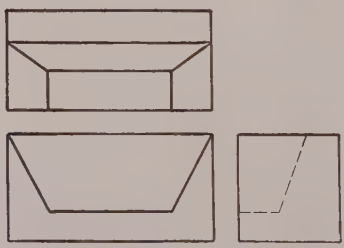
Dovetail Slide



Removable Jaw

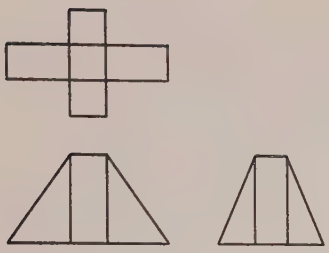


Book End

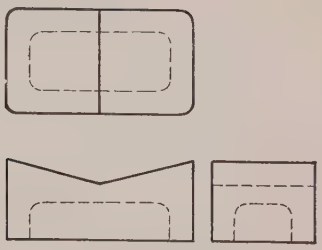


Die Block

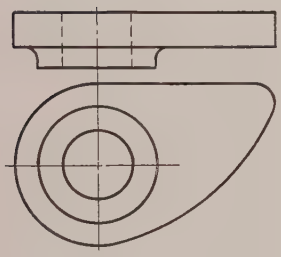
FIG. 559.—Probs. 281, 282, 283, 284, 285, 286, 287, 288. Problems for freehand sketching.



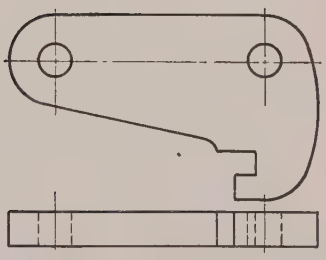
Cross Block



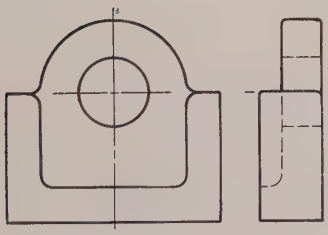
Pipe Support



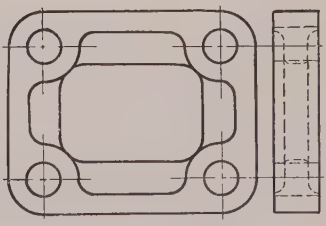
Cam



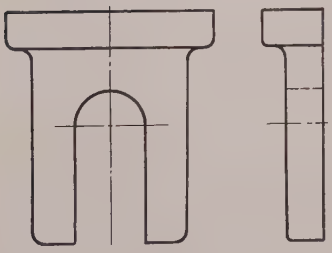
Clutch Anchor



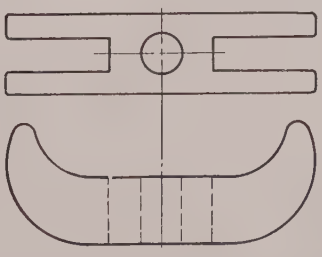
Recessed Bracket



Inspection Window Frame

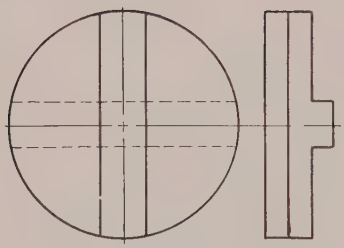


Pin Carrier

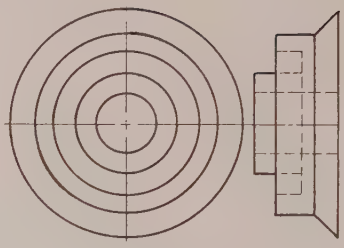


Valve Test Yoke

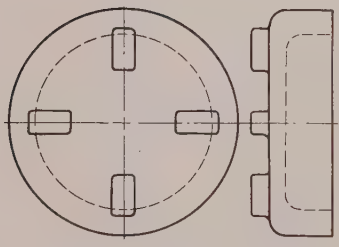
FIG. 560.—Probs. 289, 290, 291, 292, 293, 294, 295, 296. Problems for freehand sketching.



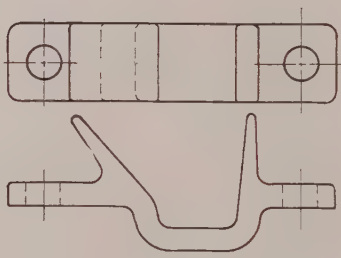
Coupling Plate



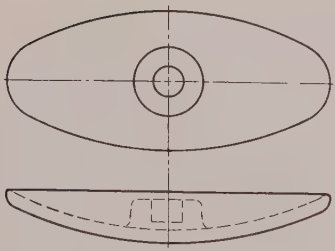
Oil Sling



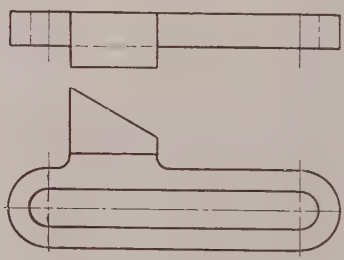
Adjusting Plug Blank



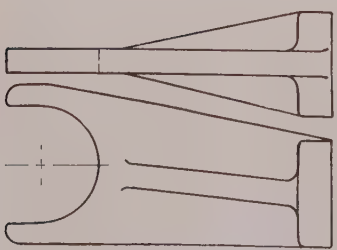
Trough Support



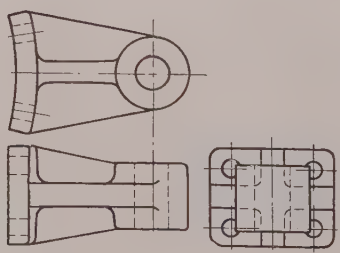
Oil Drip



Adjustable Trip



Shifter Fork Forging



Column Carrier

FIG. 561.—Probs. 297, 298, 299, 300, 301, 302, 303, 304. Problems for freehand sketching.

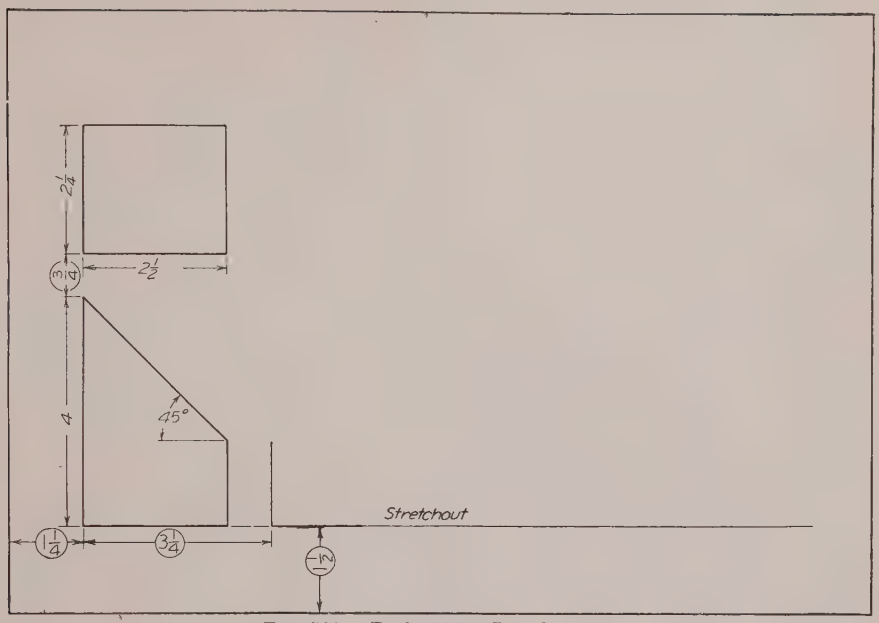


Fig. 562.—Prob. 305. Development.

Group XVI. Developments and Intersections.

Prob. 305. Fig. 562. Develop the lateral surface of the **truncated prism,** using the layout given. Read Art. 175.

Probs. 306, 307, 308. Figs. 432, 433, 434. Develop the lateral surface.

Probs. 309, 310, 311, 312, 313. Figs. 563, 564, 565, 566, 567. Develop the lateral surface.

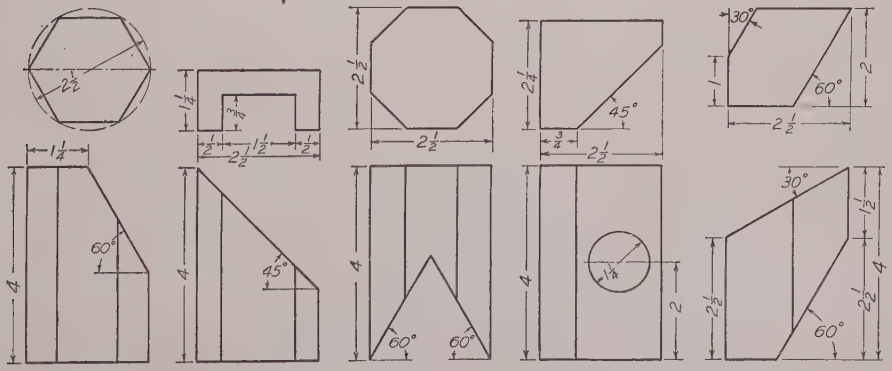


Fig. 563.—Prob. 309.

Fig. 564.—Prob. 310.

Fig. 565.—Prob. 311.

Fig. 566.—Prob. 312.

Fig. 567.—Prob. 313.

Prob. 314. Fig. 568. Develop the lateral surface of the cylinder using the given layout. Read Art. 176.

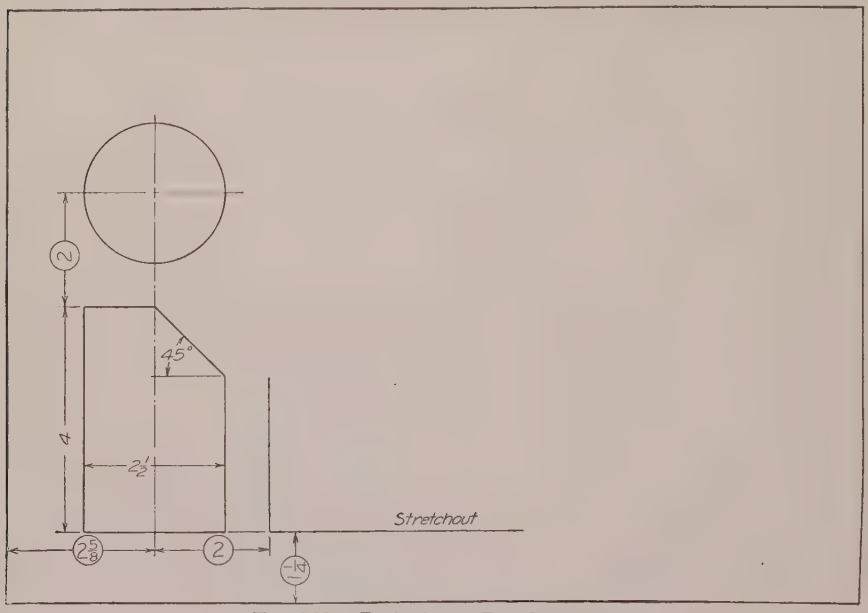


FIG. 568.—Prob. 314. Development.

Probs. 315, 316. Figs. 435, 436. Develop the lateral surface. Note that these problems include both plane and cylindrical surfaces. They may be worked on a full sheet using the layout of Fig. 568.

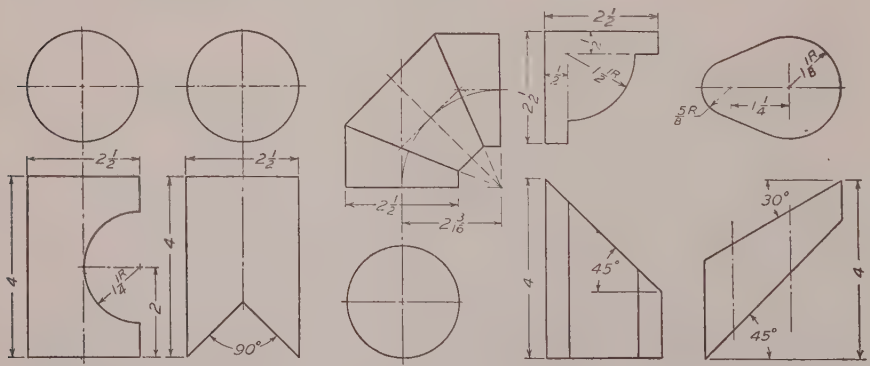


FIG. 569.—Prob. 317. FIG. 570.—Prob. 318. FIG. 571.—Prob. 319. FIG. 572.—Prob. 320. FIG. 573.—Prob. 321.

Probs. 317, 318. Figs. 569, 570. Develop the lateral surface of the cylinder using the layout of Fig. 568.

Prob. 319. Fig. 571. Develop the three-piece elbow. Refer to Arts. 177 and 178. Use a full sheet. Space the views and the pattern carefully.

Prob. 320, 321. Figs. 572, 573. Develop the lateral surface. Use the layout of Fig. 568.

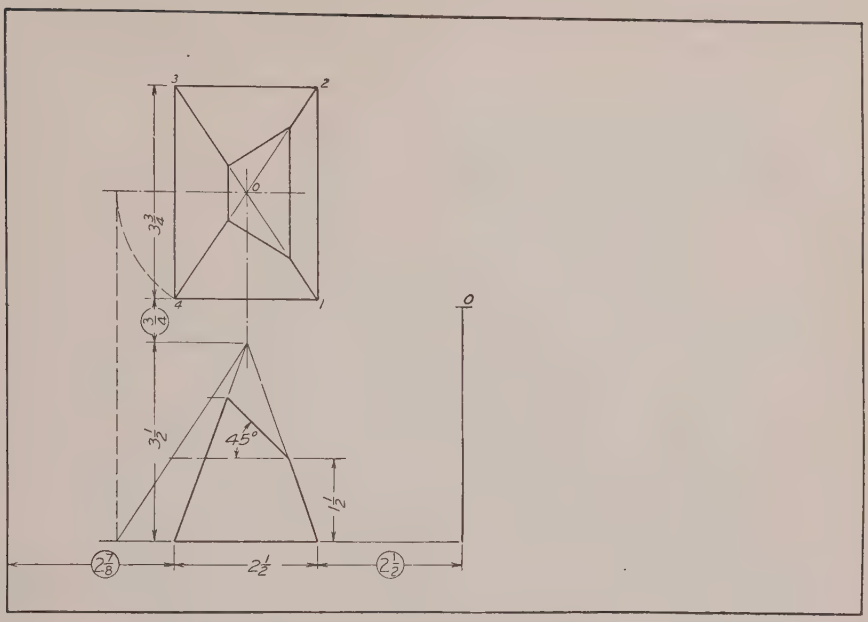


Fig. 574.—Prob. 322. Development.

Prob. 322. Fig. 574. Develop the truncated rectangular pyramid. First revolve the edge *O* 4 until its true length shows in the front view. Start with this edge in the position shown to the right of the front view. Read Arts. 181 and 182.

Probs. 323, 324, 325. Figs. 575, 576, 577. Develop the surface.

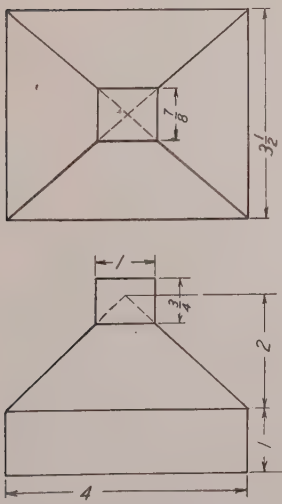


Fig. 575.—Prob. 323.

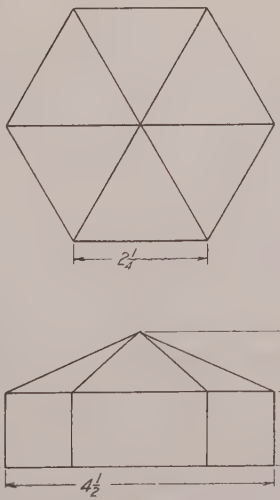


Fig. 576.—Prob. 324.

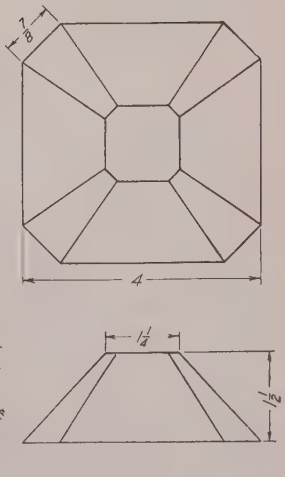


Fig. 577.—Prob. 325.

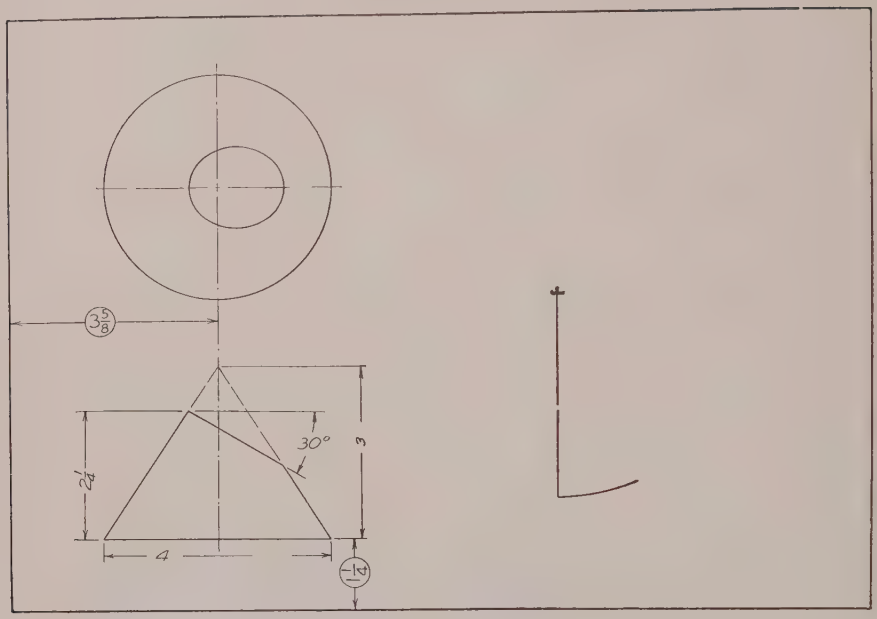


FIG. 578.—Prob. 326. Development.

Prob. 326. Fig. 578. Develop lateral surface. (Arts. 174, 184.)

Probs. 327, 328, 329. Figs. 579, 580, 581. Develop the conical surfaces.

Prob. 330. Fig. 582. Develop the **half-pint measure.** (Arts. 192 and 193.)

Prob. 331. Fig. 583. Draw patterns for the **funnel.**

Prob. 332. Fig. 584. Draw patterns for the **scoop.**

Prob. 333. Fig. 585. Make a working drawing with patterns for the **bird house.**

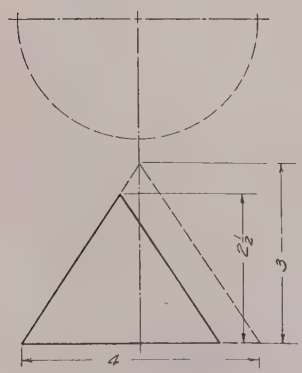


FIG. 579.—Prob. 327.

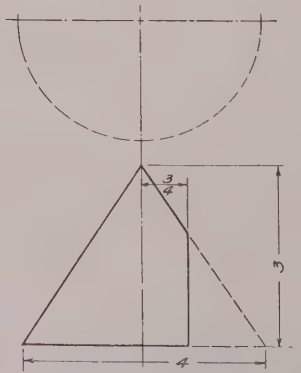


FIG. 580.—Prob. 328.

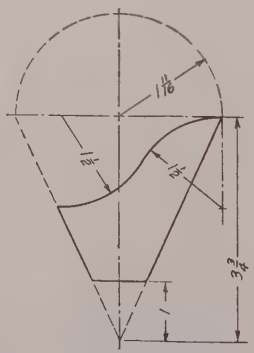


FIG. 581.—Prob. 329.

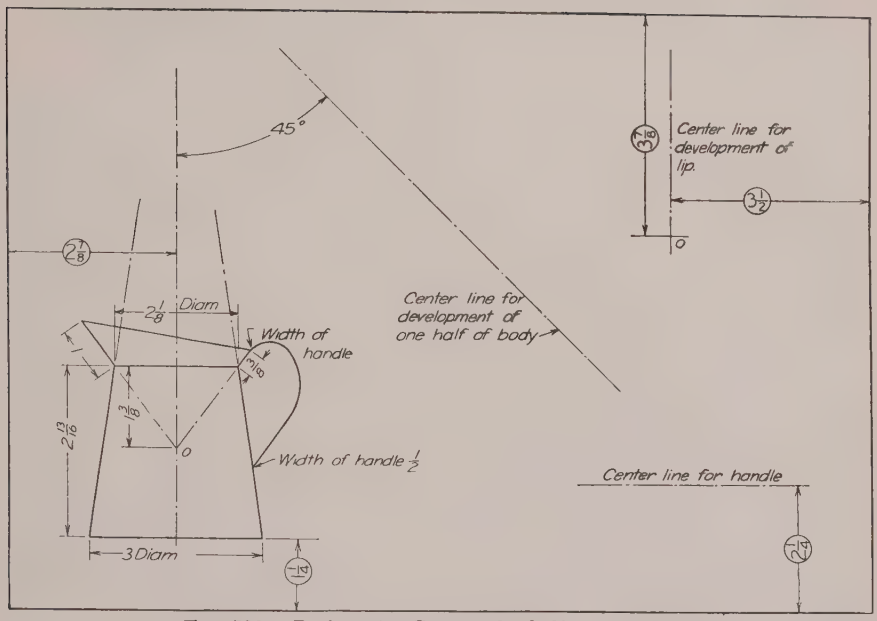


FIG. 582.—Prob. 330. Pattern for half-pint measure.

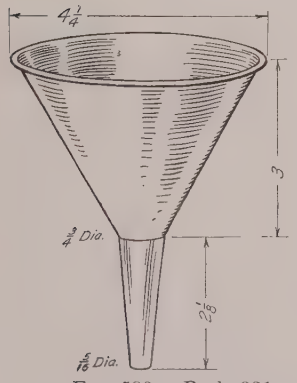


FIG. 583.—Prob. 331.

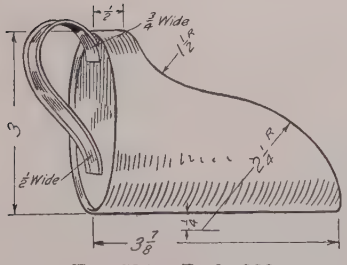


FIG. 584.—Prob. 332.

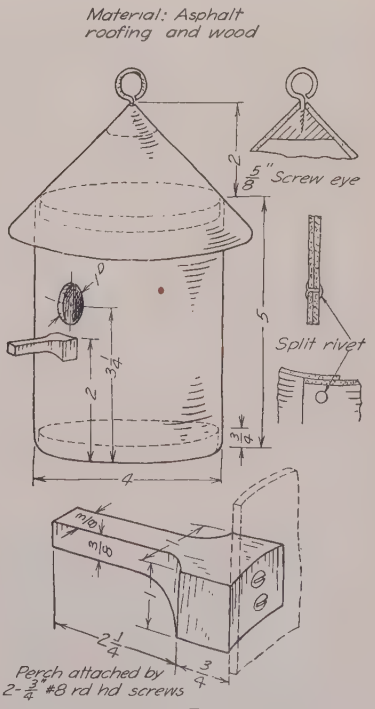


FIG. 585.—Prob. 333.

Prob. 334. Fig. 586. Draw a pattern for the **offset funnel** using the layout given. Study Arts. 181 and 185 for the general method of solution for problems of this type.

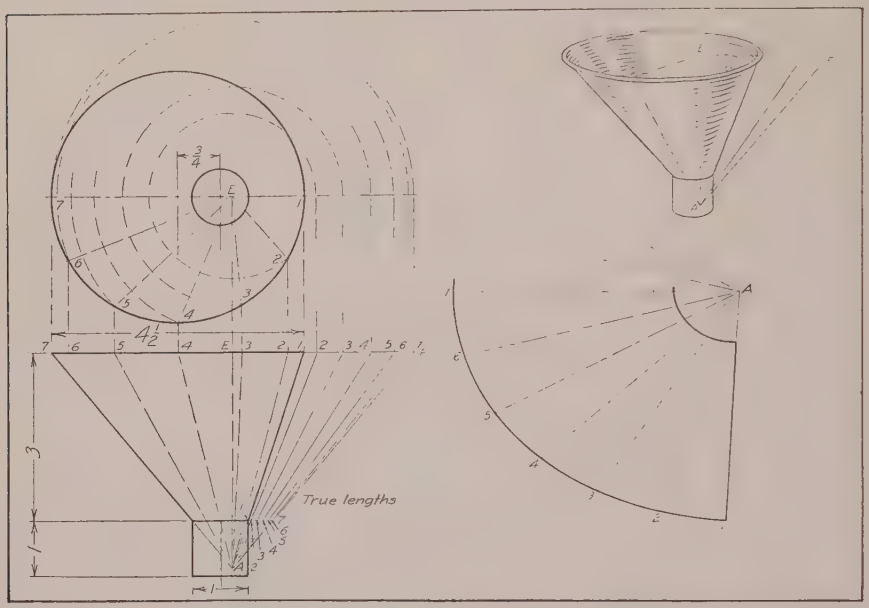


Fig. 586.—Prob. 334. Offset funnel.

Prob. 335. Fig. 587. Draw the orthographic views and the pattern for the **conductor head.** Use a scale that will be suitable for a standard-size sheet. Note that the profile is defined by an outline drawn on squared paper. Each square represents 1″.

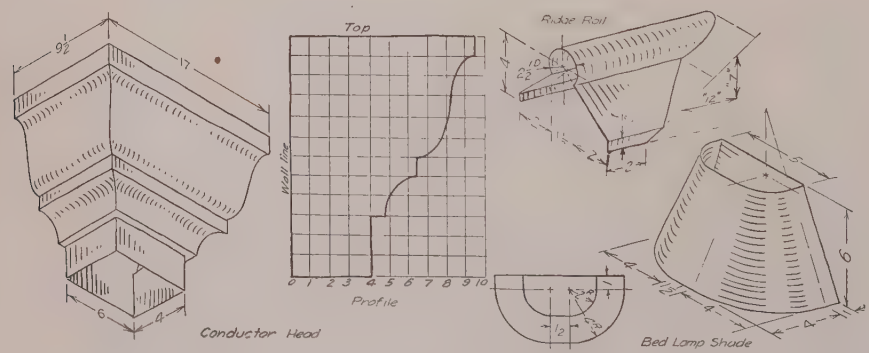


Fig. 587.—Probs. 335, 336, 337.

Prob. 336. Fig. 587. Draw a pattern for the **ridge roll.**

Prob. 337. Fig. 587. Draw a pattern for the **bed-lamp shade.** Use a scale that will be suitable for a standard-sized sheet.

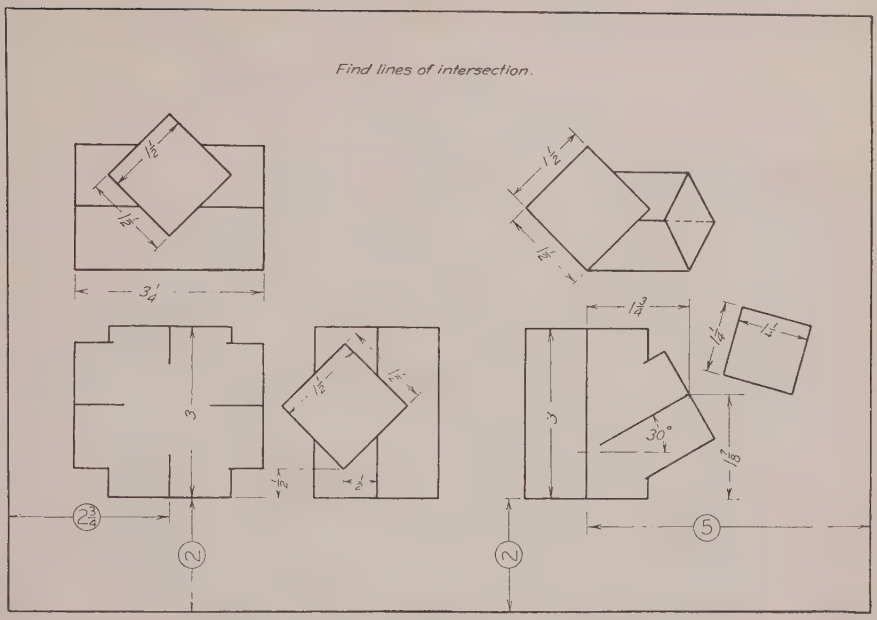


FIG. 588.—Probs. 338 and 339. Intersections.

Study Arts. 186 to 191 on intersections before beginning these problems. First observe the kinds of surfaces and the relative positions. Then see where the limiting planes are to be taken and how many planes are to be needed. Find the lines cut and locate the points on the line of intersection (where the lines cut from both surfaces by the same plane cross each other).

Prob. 338. Fig. 588. Find the line of intersection between the two prisms (Art. 187).

Prob. 339. Fig. 588. Find the line of intersection between the two prisms (Art. 187).

Prob. 340. Fig. 589. Find the line of intersection between the two prisms (Art. 187).

Prob. 341. Fig. 589. Find the line of intersection between the two prisms (Art. 187).

Prob. 342. Fig. 590. Find the line of intersection between the two cylinders (Art. 188).

Prob. 343. Fig. 590. Find the line of intersection between the two cylinders (Art. 188).

Prob. 344. Fig. 591. Find the line of intersection between the triangular prism and the cylinder (Art. 189).

Prob. 345. Fig. 591. Find the line of intersection between the hexagonal prism and the cylinder (Art. 189).

Prob. 346. Fig. 592. Find the line of intersection between the hexagonal prism and the cylinder (Art. 189).

Prob. 347. Fig. 592. Find the line of intersection between the hexagonal prism and the cylinder (Art. 189).

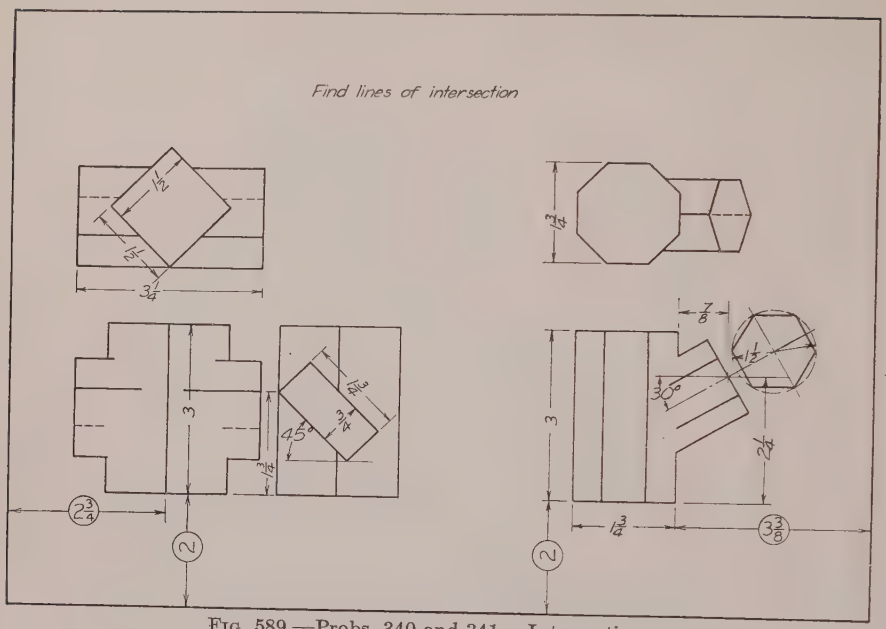


Fig. 589.—Probs. 340 and 341. Intersections.

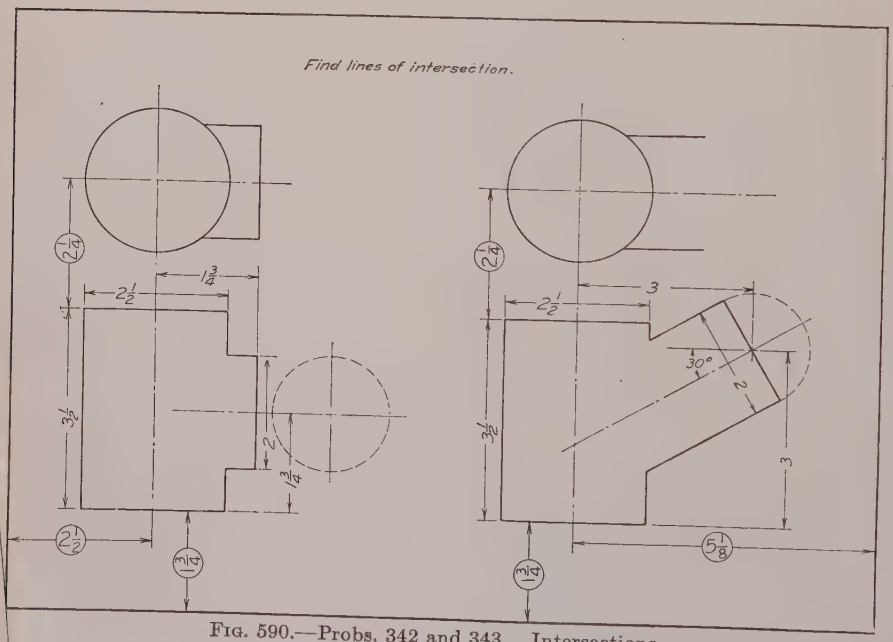


Fig. 590.—Probs. 342 and 343. Intersections.

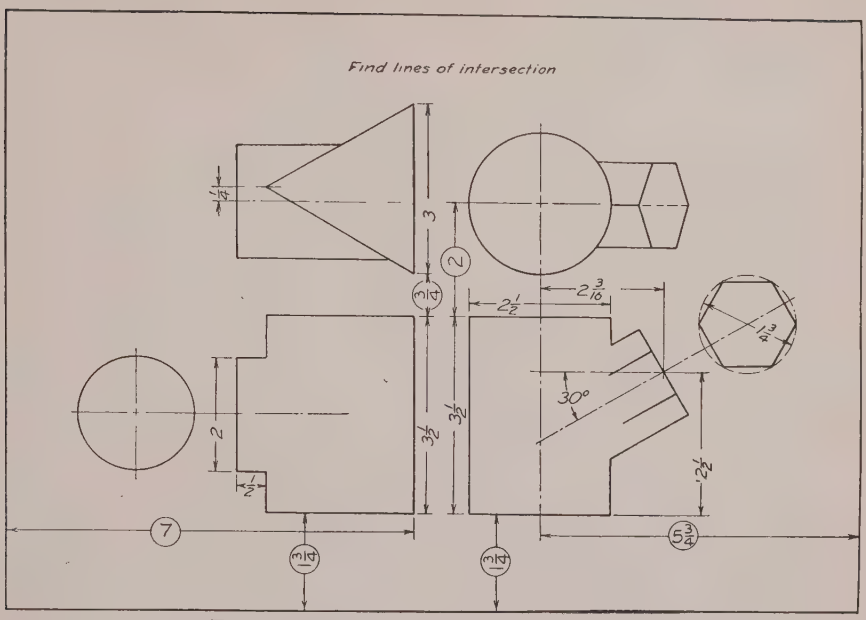


FIG. 591.—Probs. 344 and 345. Intersections.

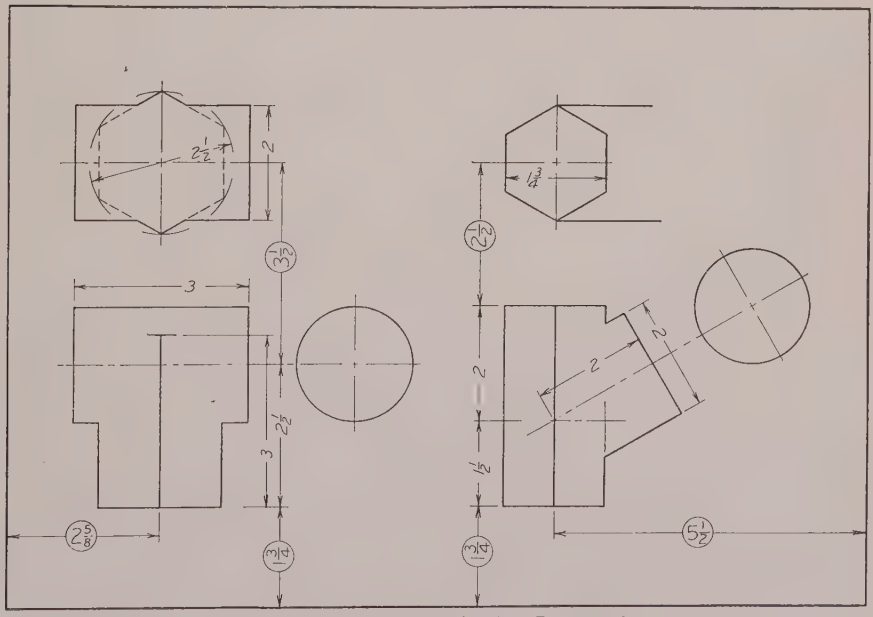


FIG. 592.—Probs. 346 and 347. Intersections.

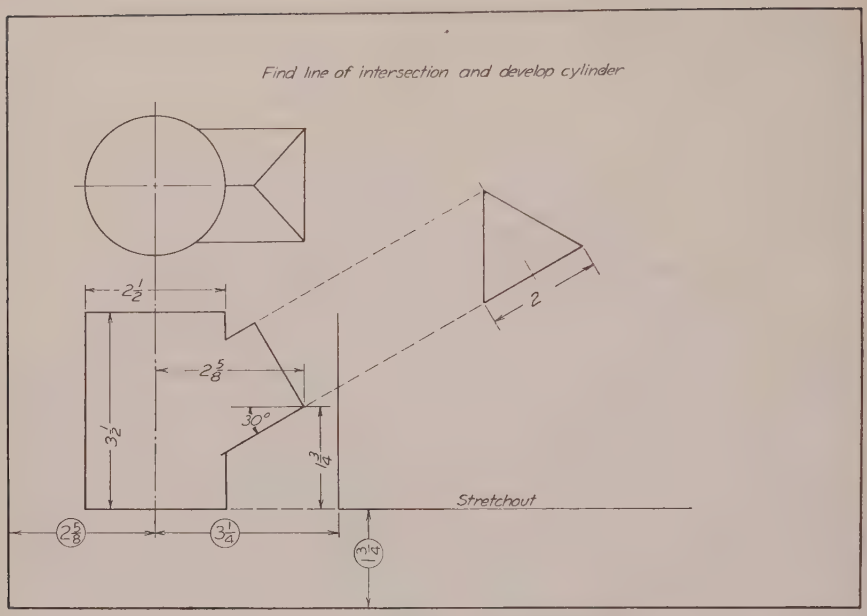


Fig. 593.—Prob. 348. Development.

Prob. 348. Fig. 593. Find line of intersection and develop lateral surface of cylinder.

Prob. 349. Fig. 594. Find line of intersection and develop the pyramid.

Prob. 350. Fig. 595. Find line of intersection and develop the pyramid.

Prob. 351. Fig. 596. Find line of intersection and develop the cone.

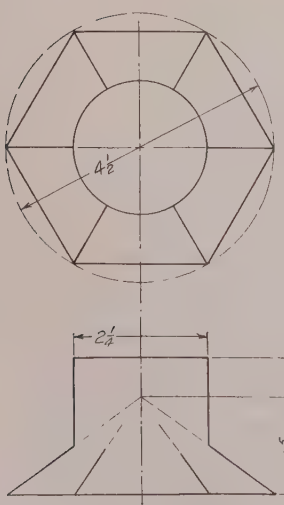


Fig. 594.—Prob. 349.

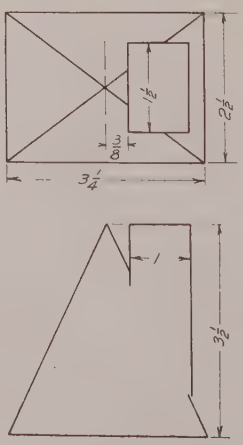


Fig. 595.—Prob. 350.

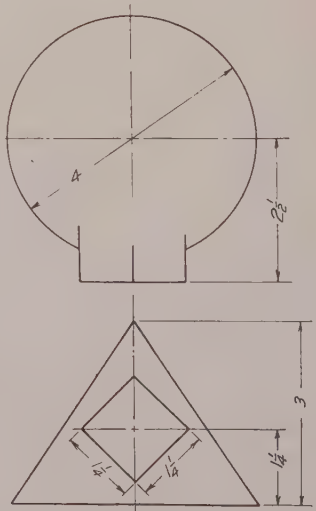


Fig. 596.—Prob. 351.

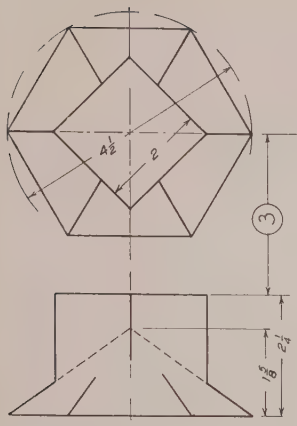


Fig. 597.—Prob. 352.

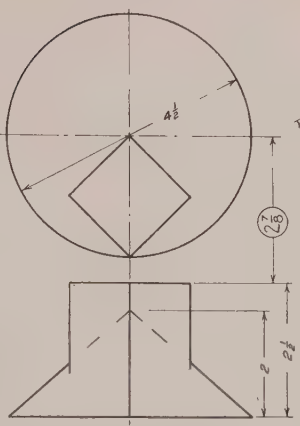


Fig. 598.—Prob. 353.

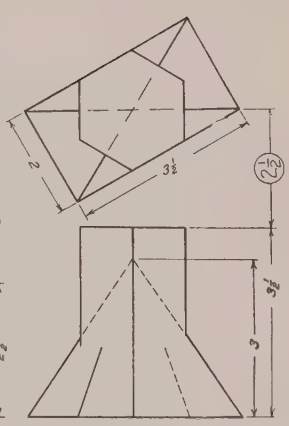


Fig. 599.—Prob. 354.

Prob. 352. Fig. 597. Find line of intersection and develop the pyramid.

Prob. 353. Fig. 598. Find line of intersection and develop the cone.

Prob. 354. Fig. 599. Find line of intersection and develop the pyramid.

Prob. 355. Fig. 600. Develop the surface of the transition piece (Art. 185).

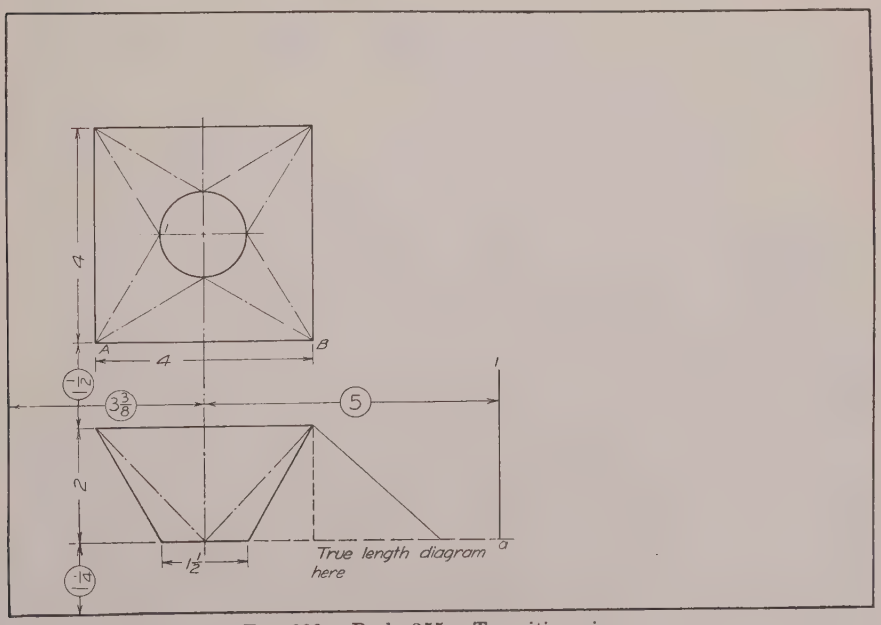


Fig. 600.—Prob. 355. Transition piece.

Probs. 356, 357, 358. Figs. 601, 602, 603. Develop the surface of the transition piece. Study Art. 185 carefully. Any of the intersection problems may be used for development by solving one problem on a sheet.

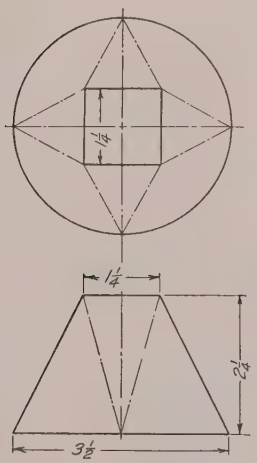


Fig. 601.—Prob. 356.

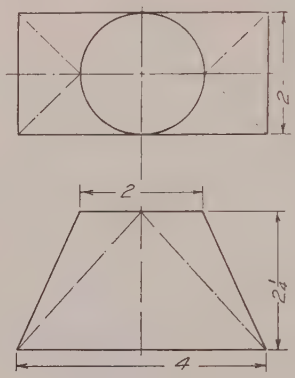


Fig. 602.—Prob. 357.

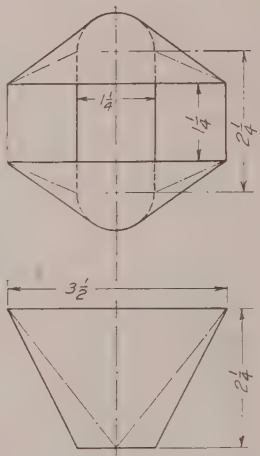


Fig. 603.—Prob. 358.

Group XVII. Architectural Drawings.

The reading and making of house plans are an important part of mechanical drawing. Several houses under construction should be visited at different stages of completion and compared with the working drawings. Study Chap. XVI carefully, especially the set of plans in Figs. 320 to 324 before starting the problems in this group.

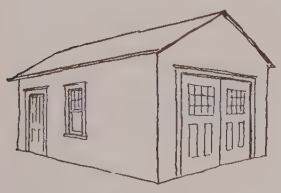
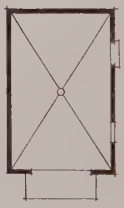


Fig. 604.—Prob. 359.



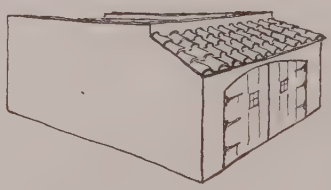


Fig. 605.—Prob. 360.

Probs. 359 and 360. Figs. 604 and 605. Draw plan and elevation for one of the garages. Size to be specified by the instructor. Refer to catalogues for over-all dimensions of automobiles.

Probs. 361 to 372. Figs. 607 to 618. Select one of the suggested plans. Make a kitchen plan showing the size and location of both movable and built-in features. Refer to catalogues and trade literature for necessary information.

FIG. 606.—Prob. 395.

FIG. 607.—Probs. 361, 373, 396, 408.

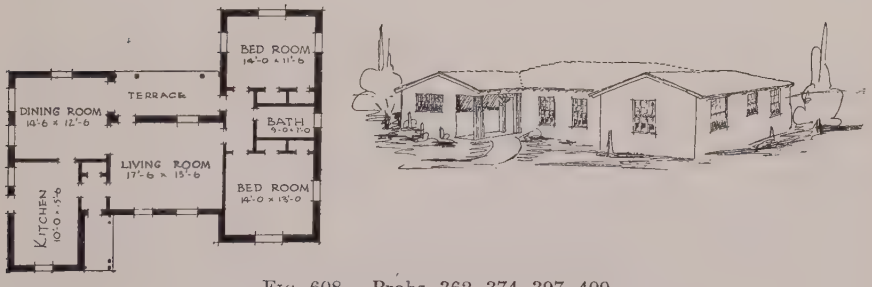


FIG. 608.—Probs. 362, 374, 397, 409.

FIG. 609.—Probs. 363, 375, 398, 410.

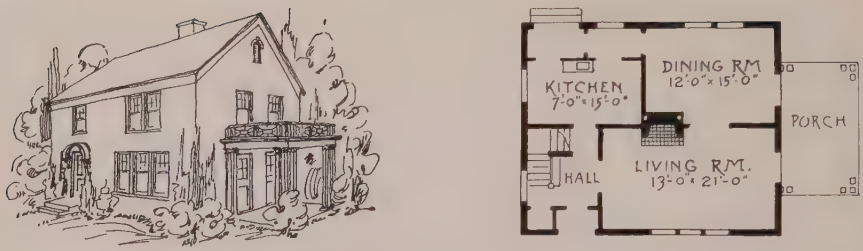


FIG. 610.—Probs. 364, 376, 385, 399, 411.

FIG. 611.—Probs. 365, 377, 386, 400, 412.

FIG. 612.—Probs. 366, 378, 387, 401, 413.

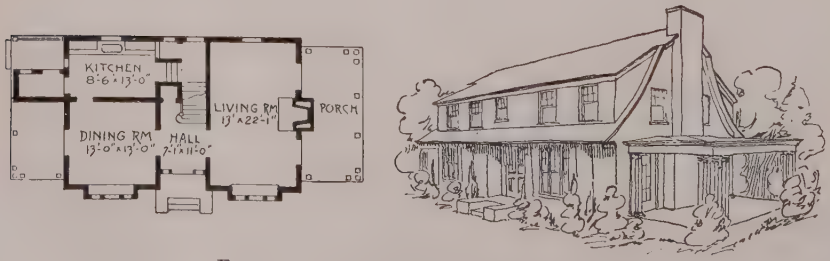


FIG. 613.—Probs. 367, 379, 388, 402, 414.

Probs. 373 to 384. Figs. 607 to 618. Select one of the suggested plans. Make a bathroom plan showing the sizes and location of the plumbing fixtures. Refer to a manufacturer's catalogue for sizes and styles of the various fixtures.

FIG. 614.—Probs. 368, 380, 389, 403, 415.

Probs. 385 to 393. Figs. 610 to 618. Select one of the suggested plans. Make a stairway diagram and draw details for the stairway. Refer to Fig. 314.

FIG. 615.—Probs. 369, 381, 390, 404, 416.

Prob. 394. Figs. 320 to 324. Make a set of plans for the house illustrated. Draw all four elevations and cabinet details if required by instructor.

Prob. 395. Fig. 606. Draw a floor plan, foundation plan, and elevations for the club house. The basement is to be omitted, so piers may be placed inside the foundation where necessary to support a central lengthwise girder on which to rest the floor joists.

Probs. 396 to 398. Figs. 607 to 609. Make drawings for one of the suggested houses as directed by your instructor. (1) Basement plan; (2) floor plan; (3) elevations—four sides; (4) details. In some sections of the country the basement may be omitted (in such cases draw a foundation plan instead of a basement plan).

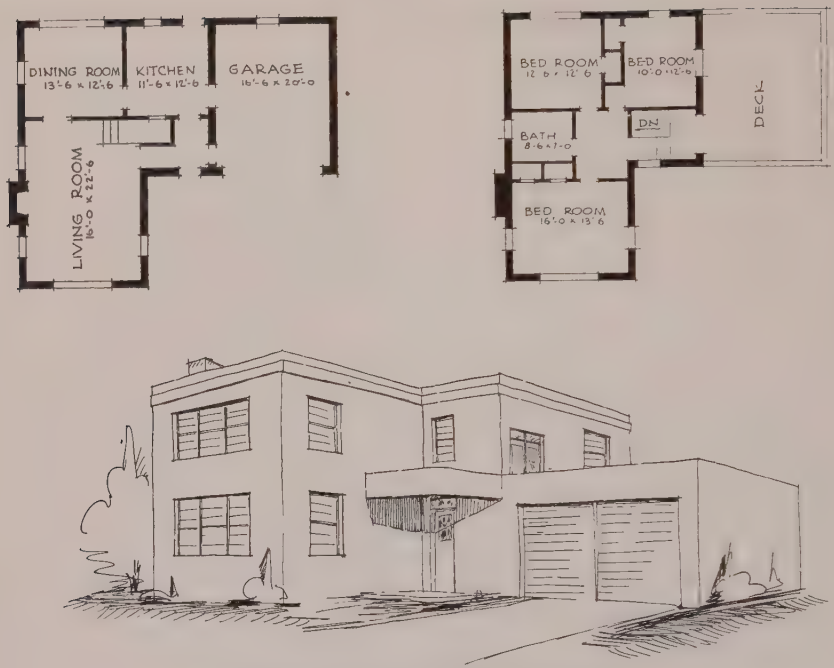


FIG. 616. Probs. 370, 382, 391, 405, 417.

FIG. 617.—Probs. 371, 383, 392, 406, 418.

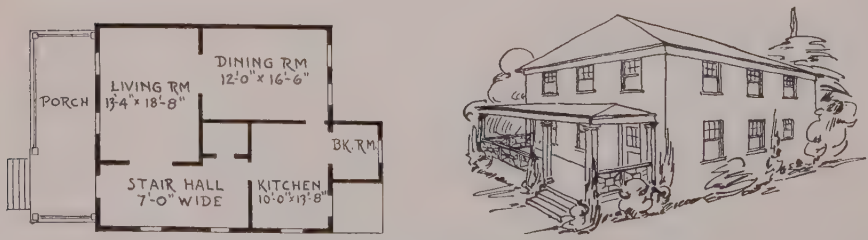


FIG. 618.—Probs. 372, 384, 393, 407, 419.

Probs. 399 to 407. Figs. 610 to 618. Select one of the sketch plans and make architectural working drawings as required by your instructor.

1. Basement plan.
2. First-floor plan.
3. Second-floor plan.
4. Front elevation.
5. Right-side elevation.
6. Left-side elevation.
7. Rear elevation.
8. Details.

Group XVIII. Structural Drawings.

Study Chap. XVII before beginning these problems.

Prob. 420. Fig. 327. Make a drawing of the structural steel shapes as shown.

Prob. 421. Fig. 328. Make a drawing showing the rivet symbols. Rearrange to make a good appearing sheet.

Prob. 422. Fig. 329. Make a drawing of the structural steel detail as shown. Consult a structural steel handbook.

Scale: $\frac{3}{4}'' = 1'$

Prob. 423. Fig. 326. Make a structural drawing of the truss as shown. Consult a structural steel handbook. Scales: $\frac{3}{4}'' = 1'$ and $1\frac{1}{2}'' = 1'$.

Prob. 424. Fig. 330. Make a drawing of the reinforced concrete detail as shown. Scale: $1\frac{1}{2}'' = 1'$

Group XIX. Map Drawings.

Study Chap. XVIII before beginning these problems.

Prob. 425. Fig. 331. Make a plat of a survey as shown.

Prob. 426. Fig. 332. Make a city map as shown, or a part of your town or city. Use dividers to transfer and enlarge the figure.

Prob. 427. Fig. 333. Make a contour drawing as shown. Use dividers to transfer and enlarge the figure.

Prob. 428. Fig. 333. Make a contour drawing similar to the figure, but show the profile on a plane closer to the front.

Prob. 429. Fig. 334. Make a contour map as shown. Use dividers to transfer and enlarge the figure.

Prob. 430. Fig. 335. Draw the conventional symbols and letter them as indicated. Make the rectangles $2'' \times 1\frac{3}{4}''$.

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